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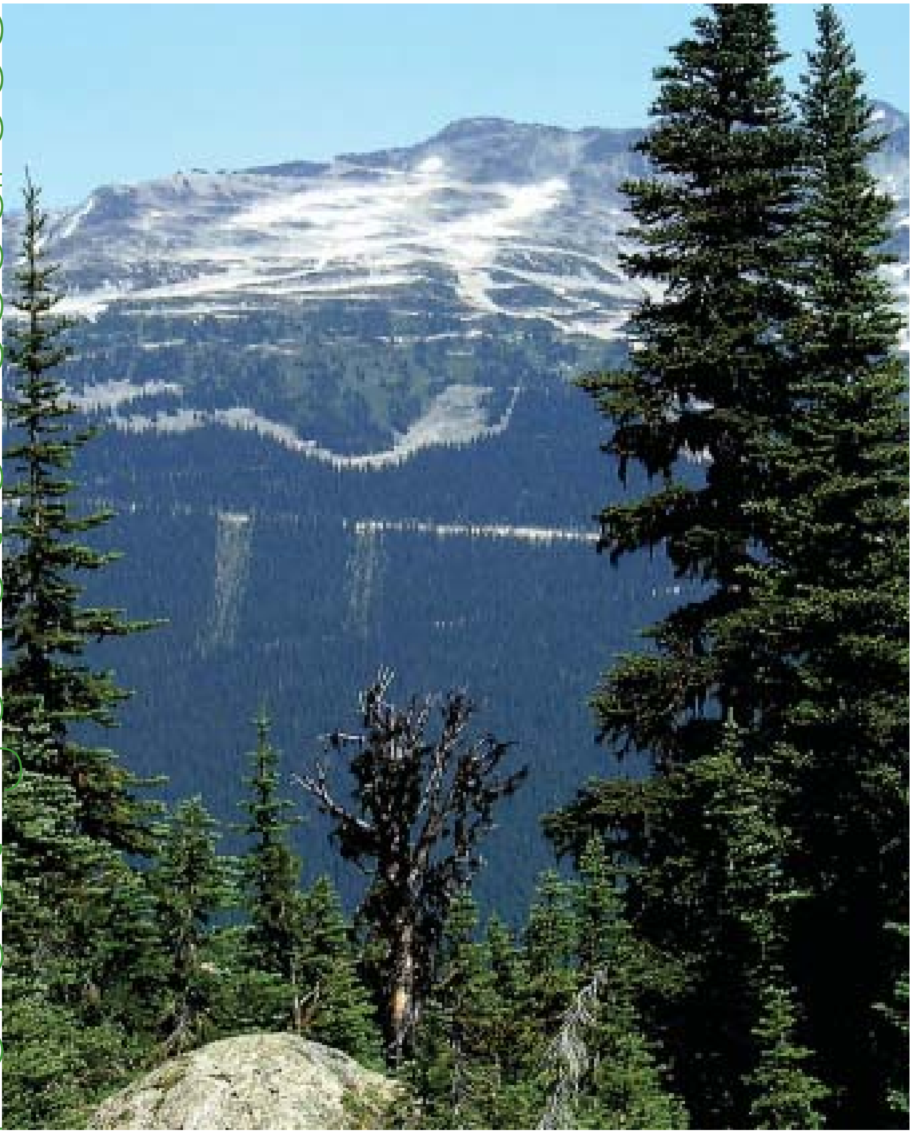
Forest genetic resources



Forest & Landscape

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Forest genetic resources conservation and management:

Overview, concepts and some systematic approaches

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Forest genetic resources

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This volume is one in a set of three guides to the conservation and management of forest genetic resources. These include:

Volume 1. Forest genetic resources conservation and management: Overview, concepts and some systematic approaches

Volume 2. Forest genetic resources conservation and management: In managed natural forests and protected areas (*in situ*)

Volume 3. Forest genetic resources conservation and management: In plantations and genebanks (*ex situ*)

The document has been prepared as a common effort between the Food and Agriculture Organization of the United Nations (FAO), the Danida Forest Tree Seed Centre (DFSC) and International Plant Genetic Resources Institute (IPGRI), and draws on inputs of a great number of national, regional and international partner institutions throughout the world.

On 1 January 2004, Danida Forest Seed Centre (DFSC) became part of the Danish Centre for Forest, Landscape and Planning, KVL. The new centre, to be known as *Forest & Landscape Denmark* (FLD), is an independent centre for research, education, advice and information concerning forest, landscape and planning at the Royal Veterinary and Agricultural University (KVL). The development objective of FLD international activities is to contribute to the increased welfare of present and coming generations, with particular emphasis on poor people, through improved planning, sustainable management and utilization of trees, forests, landscapes and other natural resources. The international activities are in part financed by Danish International Development Assistance. Contact: Forest & Landscape, Hørsholm, Kongevej 11, DK-2970, Hørsholm, Denmark.

The Food and Agriculture Organization of the United Nations (FAO) is the specialized UN agency in agriculture, forestry, fisheries and rural development. FAO provides information and technical support to member countries, covering all aspects of the conservation, sustainable use and management of forest genetic resources. Contact: FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy.

The International Plant Genetic Resources Institute (IPGRI) is an independent international scientific organization that seeks to advance the conservation and use of plant genetic diversity for the well-being of present and future generations. It is one of 15 Future Harvest Centres supported by the Consultative Group on International Agricultural Research (CGIAR), an association of public and private members who support efforts to mobilize cutting-edge science to reduce hunger and poverty, improve human nutrition and health, and protect the environment. IPGRI has its headquarters in Maccarese, near Rome, Italy, with offices in more than 20 other countries worldwide. The Institute operates through three programmes: (1) the Plant Genetic Resources Programme, (2) the CGIAR Genetic Resources Support Programme and (3) the International Network for the Improvement of Banana and Plantain (INIBAP). Contact: IPGRI, via dei Tre Denari 472/a, 00057, Maccarese, Rome, Italy.

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While staff of all three main partner institutions have been involved in each of the chapters in the three volumes, taking full institutional responsibility for the contents, lead authors are shown against each of the chapters. These lead authors are responsible for the final contents, and provide focal points for those readers seeking additional information or clarification of points discussed.

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Cover photo: High elevation stand with *Pinus albicaulis*, under threat from the exotic white pine blister rust, Whistler, B.C. (Alvin Yanchuk, British Columbia Forest Service)

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PREFACE

Forests are the single most important repositories of terrestrial biological diversity. They provide a wide range of products and services to people throughout the world. Forest trees and other woody plants help support many other organisms, and have developed complex mechanisms to maintain high levels of genetic diversity. This genetic variation, both inter- and intraspecific, serves a number of fundamentally important purposes. It allows trees and shrubs to react to changes in the environment, including those brought about by pests, diseases and climatic change. It provides the building blocks for future evolution, selection and human use in breeding for a wide range of sites and uses. And, at different levels, it supports the aesthetic, ethical and spiritual values of humans.

Forest management for productive and protective purposes can and should be rendered compatible with conservation through sound planning and coordination of activities at national, local and ecoregional levels. Conservation of forest biological diversity, which includes forest genetic resources, is essential for sustaining the productive value of forests, and for maintaining the health and vitality of forest ecosystems and thereby maintaining their protective, environmental and cultural roles.

A major threat to forest ecosystems is the conversion of forest land to other uses. Increasing pressure from human populations who aspire to higher standards of living, without balancing the sustainability of resource utilization underpinning such developments, raises concerns in this regard. It is inevitable that changes of land use will occur in the future, but such changes should be planned to help ensure that the complementary goals of conservation and development are achieved. This can be done by including concerns for conservation as a major component in land-use planning and resource management strategies.

Currently, the main problem in achieving conservation goals is the lack of adequate institutional and political frameworks that make it possible to consider choices about land-use and operational management that are fair to all stakeholders and can be efficiently implemented, monitored and regularly adjusted to meet new and emerging needs. Decisions on the conservation of forest genetic resources should be made not in isolation but as an integral component of national development plans and national conservation programmes.

The key to success therefore lies in the development of programmes that harmonize conservation and sustainable utilization of biological diversity and forest genetic resources within a mosaic of land-use options. Sustainability of action over time will be based on genuine efforts to meet the needs and aspirations of all interested parties. It will require close and continuing collaboration, dialogue and involvement of stakeholders in the planning and execution of related programmes.

In principle, there are no fundamental technical obstacles to meeting conservation objectives that cannot be overcome. In recent years, a number of activities have been initiated to further conservation and the sustainable use of genetic resources. However, practical experience of these activities has been insufficiently documented, and the lessons learned have received little attention and have rarely been applied on a larger scale. The evidence of experience is that prudent and timely measures and programmes based on the best available knowledge can make a vital contribution to the conservation of forest genetic resources. It is therefore considered of utmost importance that this experience, coupled with current knowledge of conservation theory, is made widely available in the form of generalized guidelines and procedures to serve as inspiration for others engaged in such conservation activities.

This is the first volume of a series of three that deal with the conservation of forest genetic resources (comprising trees and shrubs). This volume gives an overview of concepts and systematic approaches to conservation and management of forest genetic resources. It outlines the need to conserve these resources and focuses on some of the strategies that may be employed in doing this. In addition, the volume focuses on planning national conservation of forest genetic resources, identification of research needs in forest resources, people's participation in the conservation of forest genetic diversity, and regional and international approaches to the conservation of forest genetic resources.

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INTRODUCTION

by Weber Amaral, Lex Thomson and Alvin Yanchuk

1.1 Introduction

Forest genetic resources—the genetic diversity present in thousands of forest tree species on Earth—constitute an intergenerational resource of vast social, economic and environmental importance. Conservation of forest genetic resources is regarded here as the actions and policies that assure the continued existence, evolution and availability of these resources for present and future generations. Both the genetic resources themselves and the practice of their conservation are essentially dynamic. Accordingly, the conservation of these resources should be seen as an attempt to preserve particular groups of genotypes or populations, and their various combinations of genes. Therefore, the aim of genetic resource management is to maintain conditions in which the genetic makeup of a species can continue to evolve in response to changes in its environment. At the same time, management for conservation aims at reducing the rates of genetic erosion.

In these guidelines, we use a definition (see, for example, FAO 1989) of ***forest genetic resource*** as 'genetic variation in trees of potential or present benefit to humans'.

- **Forest** denotes a stand, population or landscape of trees, and typically other associated woody plants.
- **Genetic** refers to variation of genetic (DNA) origin, and variation of genes at different levels: (1) variation between species, (2) variation between populations within species and (3) variation between individual trees within populations. The largest variation is between species, and loss of whole species is therefore also the most dramatic loss of future options.
- **Resources** refers to the use of genetic variation—in the broad sense stated above—considered to be of potential value for humans at present or in the future.

In situ *reserve stand of* Abies grandis*, on Vancouver Island, British Columbia, now under special management prescriptions. (D. Pigott, Yellowpoint Propagation Ltd, 2003)*

Different conservation strategies and practices have been developed. ***In situ*** ('in place') conservation implies the continuing maintenance of a population within the environment where it originally evolved, and to which we assume it is adapted (Frankel 1976). This type of conservation is most frequently applied to wild populations regenerated naturally in protected areas or managed forests, but can include artificial regeneration whenever planting or sowing is carried out, without directional selection, in the same area where the seed was collected.

Immediate conservation actions can take the form of various ***ex situ*** ('out of place') conservation measures, and serve to capture and maintain genetic variation in planted gene or seed banks.

Considerable information is available on various theoretical aspects of conservation, as well as empirical experiences of conservation for a few species, but this information is often inaccessible and of limited practical value to the local forestry officials who might be routinely involved in the management of forest and natural resources. Furthermore, conservation programmes require a substantial knowledge base in order to be undertaken efficiently, but the financial and human resources and institutional support available for related research are typically limited, especially in developing countries.

In many countries the threats to forest genetic resources are major, immediate and continual. In many cases it is unwise to delay taking conservation action just because not all the relevant information is available. Prudent and timely conservation measures and programmes, based on the best available information and general conservation principles, can make a vital contribution to the conservation of forest genetic resources. Also, immediate conservation actions can allow an interval during which additional research can be undertaken to improve the efficiency of the conservation activities.

The aim of this guide, and the two other volumes in the series, is to provide decision-makers and practitioners, especially those involved in managing forests, with general guidelines on conservation of forest genetic resources.

1.2 Why do forest genetic resources matter?

Almost everywhere, there are threats to the integrity of forest genetic resources from a myriad of causes. Major threats include deforestation and changes in land use, inappropriate forest use and management practices, pollution and climate change, as well as undocumented and uncontrolled movement of germplasm.

Forest tree species are typically long-lived, highly heterozygous organisms, which have developed natural mechanisms to maintain high levels of intraspecific variation, such as high rates of outcrossing and the dispersal of pollen and seeds over wide areas. These mechanisms, combined with native environments that are often variable, in both time and space, have contributed to the evolution of forest tree species into some of the most genetically variable organisms in existence (Libby 1987).

The high levels of genetic variation that are present within many tree species can be beneficially developed and used by foresters and tree growers. Whereas agricultural crop breeders and farmers often substantially modify the growing environment to suit a specific crop species or variety, tree growers commonly identify species and provenances which can provide some improved levels of the goods and services required even without intensive selection and improvement, or intense management requirements, or major modification of the external environment. Such diverse tree genetic materials are, moreover, intrinsically well buffered against variations in soil and microclimates when deployed locally. Accordingly, forestry and agroforestry production systems depend considerably on the continued availability of these diverse genetic resources at both the species and provenance (population) levels. Intraspecific genetic variation is needed to ensure the future adaptability of the species, as well as allowing for artificial selection and breeding programmes. Accordingly, benefits from forests and trees will only be sustained if forest genetic resources remain available. In many countries, the prospects for sustainable development in rural areas will be greatly influenced by the availability of genetic diversity in both indigenous and exotic tree species.

One of the objectives of this guide is to encourage forest and land managers, planners and others whose activities have an impact on forest genetic resources, to routinely consider gene conservation in their planning and management processes, taking into account different levels of threats, patterns of land use, forest management practices and future selection and breeding programmes (see Table 1.1).

Table 1.1 Examples of FGR issues that require consideration by FGR planners and managers

Land-use changes and human activities

	Critical issues
Land-use change, i.e. loss of forests through conversion to agriculture/intensive plantation forestry/urban land uses, shifting cultivation, development of infrastructure	Elimination or impoverishment of locally adapted tree populations, causing severe genetic erosion
Replacement of native forest with plantations	Potential loss and depletion of locally adapted tree populations; introduction of potentially invasive exotic species; introduction of outside provenances that can hybridize with local species/provenances, leading to changes in local genepools
Forest fragmentation—may result in isolation of tree populations	Increased risk of inbreeding and genetic drift; loss of pollen, pollinators and seed dispersers, which may result in changes in mating system, fitness and regeneration

Native forest management

	Critical issues
Forest regeneration, particularly forest fragments interspersed in large clear-cut landscapes	Source, quality and quantity of germplasm, whether from on-site, in the form of remnant reproducing trees, soil seed bank or advance regeneration stages, i.e. juveniles; adjacent fragments and degree of isolation; and fragment's degree of degradation
Highly selective logging, particularly when harvesting removes desirable phenotypes from a small number of commercially important species	Dysgenic selection; loss and/or depletion of locally adapted populations; reduced seed set and/or increase in selfing or autocross associated with the degree of isolation between remnant trees; low market value of remaining species, increasing the likelihood of conversion to other land uses
Forest management practices, e.g. use of fire, grazing regimes, thinning operations and introduction of exotic animals, such as honey bees	Diverse and complex ecological effects which may affect regeneration, abundance and mating systems of species in different ways
Planning of reserved or protected areas, within managed forests	Selection criteria should take into account the potential to enhance conservation of forest genetic resources through targeting endangered, restricted and/or unique populations of priority tree species

Selection and breeding programmes

	Critical issues
For native species, populations conserved *in situ* could serve as important base populations	Maintain access to full range of natural variation in either *in situ* or *ex situ* conservation populations

In general, the design and implementation of forest conservation programmes are based on attributes of ecosystems, and thus little attention is given to diversity at the species and gene levels. This is particularly true in tropical rainforest ecosystems, where the high biological diversity and its complexity pose several challenges to scientists and policy-makers. They, and other interested groups, are constantly setting priorities that, in most cases, do not take into account information at the species and gene levels.

In a world where sufficient funds and resources for research and conservation are often not available, working at the species and gene levels requires an efficient use of funds, the setting of priorities, the use of new tools such as geographic information systems (GIS), modelling and molecular markers, and usually intense field work (see Chap. 2). However, concerns have been raised about the applicability and/or the usefulness of the use of genetic information and its associated costs and benefits for forest management and conservation programmes, particularly in developing countries where baseline information is either missing or scattered. This is why a careful inventory of research needs is necessary (see Chap. 4).

STRATEGIES FOR CONSERVATION OF FOREST GENETIC RESOURCES

by Erik Kjær, Weber Amaral, Alvin Yanchuk and Lars Graudal

2.1 Introduction

Although the goal of conserving forest genetic resources can be simply stated, its implementation can be very complex and expensive. With thousands of tree species distributed among several local populations (interbreeding groups of individuals), each with thousands of variable genetic loci, priorities should be set first at the species level; only then can we assign priorities among populations. It is important that data on species that are of significance to conserve, and the levels of threat to them, be collated with *in situ* and *ex situ* management approaches in mind (Namkoong 1998). In practical terms, national programmes need ways of establishing priorities for conservation that take into account the large potential number of species for which they may be responsible. Sometimes the focus may be on species, because of their charismatic appeal. Alternatively, the focus may have to be on perceived threats resulting from economic values or ecological traits: for example, species that have low population densities, highly specialized pollination patterns or particular seed germination mechanisms. Baseline information on the status of genetic diversity, a rating of species potential value, an evaluation of the threats and the potential for conservation management are some of the necessary steps for priority-setting. The outcome can be a ranking of priorities for management or a classification of species into priority groups.

In general, an effective species conservation programme needs to take into account the whole range of geographic distribution of a species, as well as the species metapopulation structure. Without this information, one cannot claim that the genetic diversity of the target species is conserved overall. Most national conservation programmes for forest genetic resources must therefore deal with the conservation of locally adapted populations.

Given the goal of conserving gene resources, tree species could be classified into three main groups:

- species for which no measures that might be undertaken would help conservation
- species that will survive even without management
- species that will survive if suitably managed (as far as resources allow).

It is important that this last category of species be identified, and resources allocated to them as a priority (Vane-Wright 1996).

In an ideal case, the geographic distribution of a species would be listed and mapped, the type and extent of threats to particular populations would be known, and methods of conservation and management would be well established. It would then be possible to evaluate the impacts of different threats, the costs and the effectiveness of different management options in minimizing the associated impacts. Priorities could then be established, based on the evaluation of those resources for economic or ecological payoffs. However, we rarely have such complete or detailed knowledge.

Many tree species that are known to be under threat of extinction are not included in conservation programmes (National Academy of Sciences 1991; Boyle and Boontawee 1995). In some instances, the genetic resources may be well conserved within protected areas, but these might represent just a small fraction of the overall genetic variation of the species. Patterns of genetic variation may often be cryptic and reductions may portend demographic collapse as either a causal or an associated agent. Therefore, demographic data, if available, is not sufficient, nor are listings of species in parks sufficient for planning conservation. However, collating such data and testing for genetic patterns of variation can provide at least initial indicators of the state of the genetic resource.

Targeting species and regions for more detailed genetic surveys can then provide information on priority species for conservation as mentioned by Koshy *et al.* (2002). These authors also suggest two levels of targeting; one for research and risk assessments, and the second for management of specific risks. Large-scale data, such as are available from geographic information systems (GIS) analyses, can provide some indications of demographic threats, and hence multiple sources of data to be collated and analysed simultaneously. In the first targeting efforts of the former IBPGR (International Board of Plant Genetic Resources, currently International Plant Genetic Resources Institute, IPGRI), the priority lists of crop species that guided collection efforts were created largely on the basis of likelihoods of demographic extinction and thus on risks of genetic erosion, made possible by a broad global sharing of common objectives and information from crop species in agricultural systems. Unfortunately, there is no such consensus for forest trees and hence more explicit statements of models and factors are needed at an international level, as well as for any country trying to establish its own priorities.

In most conservation programmes, people must make decisions about management actions, even with limited access to research data to support their decisions. In these cases, they must also decide which characteristics of the organisms involved are least known but, if studied, are most likely to make a difference in how the organisms are managed. In this sense, we are interested not so much in descriptive biology as in the biology of genetically and ecologically critical functions (Purvis and Hector 2000), such as adaptation to changing environments and potential for evolution and artificial selection. These aspects are covered in Section 2.3.2.

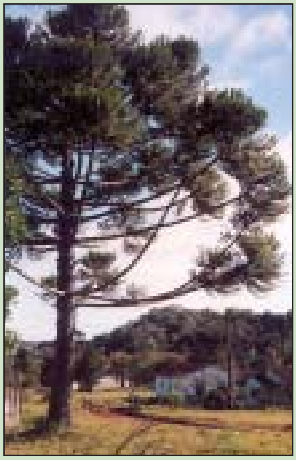
2.2 Identifying the problems and looking for possible solutions

Efforts to conserve forest genetic resources are typically driven by awareness of threats. These threats can vary in magnitude from total removal of forest cover to degradation of populations beyond biologically acceptable levels. The cause–effect relationship varies from case to case, and an understanding of the underlying problems is essential in order to develop an efficient strategy.

2.2.1 Conversion of forests to other land uses

Forests can be lost either because forest resources and trees are not regarded as being of economic importance, or because of a policy framework that makes it possible to replace forests with other land uses (for instance agriculture, pasture, mining, infrastructure development or urbanization) (see Box 2.1). Often this is based on short-term maximization of economic returns and lack of supportive forest policies based on good understanding of the potential of forests as sources of income and products for local and regional markets and their associated services for other sectors of the economy.

Box 2.1 Managing FGR in Brazil and Argentina



Araucaria angustifolia *trees within a* faxinal*, the traditional system for the communal use of natural resources.* *(Barbara Vinceti/IPGRI)*

Demographic and market changes are putting additional pressure on the sustainable use of forest resources in areas where traditional systems of use are still in place. Systems that have functioned in the past have led to overexploitation in more recent times, as a result of population growth and changes in agricultural policies. This is particularly true for the rubber-tapping communities in the Amazon and the Mapuche Indians in the southwest of Argentina, as well as in the market demands of faxinal systems, an example of a collective property rights management regime for forest lands, in the Paraná state of Brazil. The same forces make the development and implementation of new and alternative land uses difficult. Upfront costs for the adoption of sustainable forest practices are high, and revenues from better practices are uncertain and often only achieved in the mid- to long-term future.

An additional problem is that the ecological and economic knowledge needed to change current practices is not always available, so considerable research efforts to generate and gather information are required. This also implies costs and time that the local communities normally cannot afford. Inputs and actions from governmental and non-governmental organizations (NGOs), scientists and researchers directly involved with these issues are therefore needed.

Clearly, public concern about environmental degradation has two faces. For example, in Argentina and Brazil, it has already resulted in many new environmental and conservation policies. Some of these policies aim to restrict the use of forest resources, thus making it more difficult for local communities to have a source of income from the forests. The case of the *Araucaria* tree species in Paraná is a good example of a policy that has had counterproductive effects. The ban on logging *Araucaria angustifolia* has led to a lack of interest by local communities in planting this species, which is consequently becoming increasingly threatened. Other policies have had positive impacts, such as increased demand for certified forest products. An example of a policy with positive effects was the imposition of constraints on the migration to forest areas of newcomers who might not only disrupt existing social and economic structures but also cause additional pressure on the ecosystems themselves. In Paraná the arrival of immigrants from southern states has been mentioned as one of the factors causing the decline of the faxinal systems. The example of the state of Acre (Brazil) shows that new settlements, established within the framework of the Agrarian Reform in areas with a long tradition of sustainable land use, also cause land conflicts and increased pressure on forest resources. Within the new settlements, land ownership is secured by clearing the forest. This is in complete contradiction to the traditional way of using forest resources—the exploitation of non-wood forest products (e.g. collection of fruits of forest tree species, rubber extraction within reserves), based on the maintenance of a permanent forest cover.

(Provided by W. Amaral, IPGRI)

2.2.2 Unsustainable utilization

When tree species are regarded as valuable, unsustainable patterns of utilization are another threat to genetic resources. The problem is typically related to the frequency and intensity with which trees are harvested, for either timber or non-timber production, and how the forests respond at species and ecosystem levels after the logging activities.

Degradation of the genetic resources may not involve removal of all trees; it may take the form of selective logging, leaving only trees with lower fitness for future reproductive cycles and thus affecting future seed harvests and natural regeneration, and therefore economic benefits, in the long run (see Box 2.2).

Box 2.2 Degradation of teak in Thailand

Girdling of teak tree (Tectona grandis) *one year before felling. (H.Keiding/DFSC, 1959)*

Teak *(Tectona grandis)* is one of the most important plantation species in the world. It grows naturally in the northern part of Thailand in mixed deciduous forest at an elevation of 100–900 m (Mahapol 1954). The total area covered by natural teak forest in Thailand fell from 65 000 km^2 in 1960 to 21 000 km^2 in 1990. The present deforestation rate may be as high as 2 000 km^2 per year (CCB 1995). Large areas of teak forest still exist, but in many parts of the remaining forests, outside protected areas, logging takes place to such a degree that in a few years almost no straight trees will be left. Obviously, the conservation status of the species is gradually deteriorating. This has led to the development of a plan for conservation of the genetic resources of teak in Thailand (Graudal *et al.* 1999).

Further threats to forest genetic resources such as teak could also originate from increased plantings of imported or less adapted sources of germplasm. This could eventually lead to the spread of foreign alleles into the remnant local populations. Also, if all planted trees originate from a few, easily accessible and abundant fruiting mother trees, this could lead to another problem associated with small effective population sizes in future generations, and thus reducing potential selection programmes and productivity.

(Provided by L. Graudal)

2.3 Objectives, priorities and approaches

2.3.1 What to conserve: ecosystems, species or genes?

The first step in genetic conservation is to specify the objectives of the conservation programme. This is of the utmost importance, since it is possible to conserve ecosystem properties and still lose species entities. It is also possible to conserve a species and still lose genetically distinct populations, and therefore, genes that may be of value in disease and pest resistance, and in future adaptation. They could also be important in species deployment through breeding programmes, if that becomes a need or necessity.

Many forest genera and species around the world provide goods and services, such as timber, wood, food, fodder, environmental stabilization, shade, shelter, and cultural and spiritual values. However, fewer than 1 000 tree species have been systematically tested for their present-day utility, and less than 100 are the subject of intensive genetic research programmes. Evidently, therefore, many different forest species are being used *in situ* to provide important goods and services, without any active genetic management.

Worldwide, the conservation of forest genetic resources has as its overall objective the maintenance of genetic diversity in the thousands of tree species of known or potential socioeconomic and environmental importance. Moreover, the levels and distribution of genetic variation in any given species are expected to be in a process of constant natural change resulting from the main forces of evolution. Therefore, the central concern of conservation should be the evolutionary processes which promote and maintain genetic diversity, and not the endeavour to preserve the present distribution of variation as an end in itself (Namkoong *et al.* 1997; Namkoong 2001).

2.3.2 Assessing species' priorities for conservation action

Within any given country or local area there may be divergent opinions on priorities among tree species. Forestry departments are likely to have a somewhat different emphasis and priorities from those of local forest dwellers and users, which can be different again from those of farmers and various other users of trees. It is apparent that *in situ* conservation programmes will be more successful if they target species of direct interest, use or concern to the land management authority and/or landowner(s): this will have major implications for the planning of *in situ* conservation programmes. A participatory rural appraisal approach (see Chap. 5) can be useful for helping local communities whose land is communally owned to better identify their priority tree genetic resources and to develop appropriate *in situ* conservation responses.

It is also important to consider the case for species and provenances which are of major economic importance when planted as exotics, but currently of much less significance in their native range and habitats; an example is *Pinus radiata* from the south-western USA and Mexico. In such cases it is not unreasonable to expect that the likely beneficiaries of *in situ* conservation should contribute, financially or otherwise, to conservation.

Given that there will be limited financial resources available for specific conservation programmes for forest genetic resources, it is necessary to consider which of the priority species are also in most need of, or warrant, conservation interventions and actions. This can be conveniently undertaken for different species by comparing the extent of the resource (level of genetic diversity or intraspecific variation) with the vulnerability or threats to the populations and/or ecosystems of which they are a part.

As an example, in Table 2.1, Koshy *et al.* (2002) present a decision-making approach for setting priorities for conservation of tree species in different sites in tropical semi-deciduous forests in the state of Sao Paulo, Brazil. The **decision tree approach** is based on the use,

Table 2.1 Score of five highest-and lowest–ranking species among 267 (Sao Paulo State, Brazil)

No.	Species	Sites Caetetus	Morro	Utility Weight	Score	Ecological Weight	Score	Threat Weight	Score	Final Score
1	*Myroxylon peruiferum*	X	X	2	37.2	4	69.9	5	53.3	620.5
2	*Euterpe edulis*	X		2	35.4	4	74	5	49.6	614.8
3	*Hymenaea courbaril*	X	X	2	45	4	69.9	5	48.8	613.6
4	*Jacaratia spinosa*	X	X	2	39	4	72.4	5	44.2	588.6
5	*Maclura tintoria*	X	X	2	27	4	80.9	5	40.4	579.6
...										
263	*Senna pendula*	X	X	2	25.6	4	33.3	5	15.1	259.9
264	*Aegiphila sellowiana*	X	X	2	20.2	4	35.6	5	13.5	250.3
265	*Piptocarpha sellowii*	X		2	7	4	41.1	5	13.5	245.9
266	*Croton floribundus*	X	X	2	25	4	27.4	5	15.1	235.1
267	*Senna bifora*	X		2	8.2	4	35.7	5	14.5	231.7

Source: Koshy *et al.* (2002)

ecological and threat values, scored by a spectrum of stakeholders including scientists and researchers, farmers, local peasants and business people. The species with the final highest scores are those which should be given priority for conservation.

In general, conservation strategies of genetic resources have been grouped into *in situ* and *ex situ* categories. The establishment of national systems of protected areas (mainly for *in situ* conservation purposes) and the creation of public and private reserves are conservation practices that are becoming adopted worldwide. More recently, private land and agriculture areas (such as on-farm conservation) are also being considered as integral elements of conservation strategies, using a landscape and an integrated approach of protected areas within agricultural landscapes.

2.3.3 *In situ* conservation strategies

In the case of non-domesticated species, *in situ* conservation is probably the most important strategy and sometimes the only viable approach. In the tropics, where extinction rates of species are high because of land-use changes, setting conservation priorities is critical. This is particularly evident in developing countries, where resources allocated for conservation are scarce and baseline information on species distribution and richness data are lacking. In a world of scarce resources, one approach to priority-setting is through networking activities, with initiatives involving multiple countries and stakeholders (James 1999).

In situ conservation is usually the preferred conservation strategy for most wild plant species, including some of the wild relatives of crop species, because, as mentioned previously, it allows the populations of interest to continue to be exposed to evolutionary processes. Alternatively, for many domesticated species (crop and livestock), on-farm conservation of traditional varieties is now widely supported as an important practice for conservation of genetic diversity (Hodgkin 1996; Jarvis *et al.* 2000).

Molecular genetic studies, carried out on many forest tree species around the world, are contributing to a better understanding of patterns of variation to support the development of improved management practices, and to monitor changes of species turnover in time and in space (Hamrick 2001). In some situations, these priorities could be refined by the use of new tools, such as molecular markers and modelling simulations. Integrating GIS tools with molecular research will improve our knowledge of landscape patterns of genetic diversity of species distribution, and help develop resource management plans. For example, in the Western Ghats, India, these two approaches are being used in combination to detect areas with high diversity (intra- and interspecific) and to set priorities for conservation (Boffa 2000). Molecular markers can thus assist in the conservation of tree species and may allow national programmes to reflect biodiversity patterns in their own management plans. Molecular methods can also help to identify differences between local and non-local provenances and genotypes, identify where diversity is being lost, and facilitate the introduction of new diversity for integrated conservation and breeding programmes. This can also provide for a better management of intraspecific genetic variation (Brown and Kresovich 1996; Karp 2000).

2.3.4 *Ex situ* conservation

Ex situ conservation is considered to be the foundation that ultimately allows the use of genetic diversity in plant breeding and conservation. The essential elements of *ex situ* conservation are related to the need to identify, then conserve and manage the range of variability within the species, primarily through the development and management of regeneration, in various forms, in the field. Molecular genetic techniques, primarily with genetic markers, can also help in some of the management tasks for *ex situ* populations, by confirming the identity of accessions and monitoring genetic changes in collections. However, the allocation of resources in genetic conservation should be need-driven rather than technology-driven (Withers 1993).

Biotechnology can also make contributions to the management of germplasm banks by providing better tools to assess levels of genetic diversity, and providing new alternatives to maintain genetic stocks. New molecular techniques avoid redundancy and duplication within collections through fingerprinting analysis and genetic diversity studies (Brown and Kresovich 1996; Karp 2000). Another widely used biotechnology tool, cryopreservation, aids the long-term storage of several plant accessions (Withers and Engelmann 1998). Molecular tools such as those now being used in genomic studies can assist in the identification of potentially useful genes in genebank accessions. Examples of marker applications are given in Table 2.2.

2.4 Genetic processes: evolutionary versus static conservation strategies

The focus on whether or not to maintain genetic processes as part of the conservation strategy is important when deciding the choices of options for conservation. Genetic processes typically deal with changes of gene frequencies and genotypic distributions. Examples of circumstances leading to such changes are:

a. Random losses of alleles, random changes in gene frequencies and/or increased levels of inbreeding that may occur if the populations are small, or seed is collected from relatively few trees. All activities that reduce population size will generally increase the rate of inbreeding.
b. Management and/or use of natural populations that (1) influence the behaviour of pollinators and seed dispersers that can lead to changes in the amounts of inbreeding and/or change fertility, or (2) alter microclimate and/or species composition, thus inducing new competitors.
c. Intended or unintended selection due to the use and/or management of natural stands, or during propagation and management of plantings—both can favour or disfavour certain alleles and thereby change allelic frequencies.
d. Continued natural selection to the prevailing environment that affects allele frequencies (as well as natural selection against inbred offspring in species with a

Table 2.2 Molecular markers currently in use in FGR diversity research: properties and applications

Marker/properties	Description	Properties*	Applications	Polymorphism**
Isozymes	Protein expression markers—phenotypic marker	Co-dominant	Population genetics studies and mating system studies	Low to medium
RFLPs	Restricted fragment length polymorphism	Co-dominant	Genetic diversity measurements; characterization of genetic material	High
RAPDs	Random amplified polymorphism	Dominant	Genetic diversity measurements	Medium
AFLPs	Amplified fragment length polymorphism	Dominant	Genetic diversity measurements	High
SSRs	Single strand repeats (microsatellites)	Co-dominant	Population genetic studies	High
STS	Sequence tag site	Co-dominant	Population genetic studies	Medium to high
SNP	Single nucleotide polymorphism	Co-dominant	Phylogenetic and population studies	Very high
Gene sequencing	Chloroplast (cpDNA); mitochondrial (mtDNA); nuclear (nDNA)	Dominant	Phylogenetic and population studies	Low to medium
DNA chip array	Microarrays of DNA sequences	Dominant	Genotyping and gene expression studies	High

* Properties: dominant (lack of capacity to differentiate homozygotes from heterozygote individuals; co-dominant (capacity to detect heterozygotes, or individuals with two different alleles in the same locus).
** Polymorphism: indicated here as the capacity to detect polymorphic loci, based on heterozygosity measurements.

mixed mating system, i.e. species that under natural conditions produce a mixture of selfed and outcrossed progenies).

Processes (a) and (b) are typically considered to be undesirable in all conservation strategies, because they lead to random loss of genetic diversity, and/or decrease the fitness of the populations. However, to some extent, processes (c) and (d) reflect a genetic response in favour of continued adaptation to the given environment. It is therefore important in the planning process to consider to what extent these processes are unacceptable, acceptable or even desirable. This will of course depend on the objective of conservation.

Roughly speaking, conservation strategies can also be separated into three categories in terms of the evolutionary process (following Guldager 1975):

- **Static conservation strategies,** where genetic processes are typically not considered important. The aim is to keep gene frequencies or genotypic distributions as unchanged as possible. One can say that the objective is *preservation of the current set of genotypes in the collection or sample.*

- **Strict evolutionary conservation strategies,** where protection of genetic processes is considered as important as the conservation of the actual gene frequencies in the population, or more so. One can say that the objective of evolutionary conservation is to protect *populations that can maintain fitness through long-term adaptation* (for example the development of landraces), so there is the expectation that gene frequencies should change. Here processes associated with (c) and (d) above are seen as being elements of the conservation, and these processes are therefore protected or even supported.
- **Evolutionary conservation for utilized populations,** where the objective is to conserve genetically diverse, viable populations, growing under conditions that reflect the managed and used forests or plantings.

2.4.1 Static conservation: clonal archives, seed banks and cryopreservation

Static conservation activities are characterized by the fact that **genotypes** are the targets for conservation. Therefore, vegetative propagation is in general preferred to propagation by seed. Vegetatively propagated clones can be planted and protected in **clonal archives**. The grafted or rooted trees will often be able to grow to a considerable age if the grafting has been a success. Of course, at some future date, the trees have to be re-grafted on new rootstock. It is important to maintain the archives carefully in the early years in order to avoid shoots or sprouts of the rootstock taking over the grafted scion material. Constant weeding and tending is required, and good labelling and maps are essential. Static conservation thus requires continual, fairly intense, human management.

Static conservation is also applied to conserve seed lots in **seed banks**, where seed is kept in cold storage, or under otherwise favourable conditions. Seed banks can only be used for conservation of species with storable seed. A large number of tropical tree species have so-called **recalcitrant seed**, which dies within a few years of storage. The vast majority of species have seed that can only maintain a high germination rate for relatively few years compared to the lifetime of the living tree, and the seed lots therefore need to be regenerated from time to time. This will include germinating the seed, producing the seedlings, growing the trees until they start flowering, and collecting new seed for storage. These ‘rejuvenation’ activities allow for new genetic recombinations and new selection pressures during propagation and growth.

Aerial view of clone banks at Cowachin Lake Research Station, Vancouver Island, British Columbia. (B.C. Ministry of Forests)

For most species, seed banks should probably be seen as a short-term conservation activity. Seeds from endangered populations can be collected and stored in the seed bank for an interim period until they can be sown, seedlings grown and gene conservation plantings (the so-called *ex situ* conservation stands) established. The role of such *ex situ* gene conservation plantings in an overall conservation strategy is discussed further below; a comprehensive account of the technical details is given in Vol. 3, Chap. 5, and technical details of seed banking itself are given in Vol. 3, Chap. 6.

For many species, particularly those from the moist and semi-moist forests in many parts of Africa, seed banks cannot be used even for short-term conservation because the seed cannot be stored for more than a few months. *In vitro* conservation, including cryopreservation, has been tried for such species, but this is also a static conservation approach. Depending on species and technique, some genetic changes (such as mutations) may take place during *in vitro* growth and storage, sometimes observed as so-called somaclonal variation (Fourré *et al.* 1997). However, the major disadvantages of the *in vitro* approach are the associated costs, the requirement for a stable supply of electricity, and—most important—the fact that a limited number of genotypes can be conserved. *In vitro* conservation techniques are, therefore, probably of little general use in efforts to conserve forest genetic resources, whereas seed banks can be important for short-term storage of some species as an interim phase until more suitable techniques can be applied.

Many species (such as several *Acacia* species with hard-coated seed, or most *Pinaceae* species) can maintain a high germination rate for many years during storage. For these species, seed banks can serve more than a short-term storage function. Genebanks for such species are a static strategy, because gene frequencies and genotypic distributions will remain largely the same as long as all seed germinates. Once the germination rate starts to drop, selective effects may take place during storage, but in general may not be related to fitness and utility of the genotypes or seedlots in the long term.

Static conservation can be an interesting option in connection with an intensive breeding programme, where identified and tested genotypes (clones) are grafted and kept in clonal archives, or used in seed orchards or clonal production hedges. One can say that in such a programme static conservation is used to conserve well-known genotypes, but evolutionary aspects are developed and managed in the breeding and testing programme over generations. In a way, then, static and evolutionary approaches can be considered complementary and used in combination.

2.4.2 Evolutionary conservation in protected and designated reserve areas

Evolutionary conservation activities are characterized by programmes where the trees produce progeny in successive generations: genes are generally 'conserved', but genotypes are not. Natural selection takes place among trees with new allelic combinations that either favour or disfavour different genotypes. This process ensures that gene frequencies will change in the population: alleles with positive influence on fitness will increase, and alleles associated with low fitness will decrease. If the population size is sufficient, neutral genes should, in general, be maintained, but some genes will inevitably be lost by genetic drift; new genetic variation will arise by mutation after several generations. Human interventions (if any) are designed to facilitate moderate genetic processes rather than to avoid them. Genetic variation between populations is generally maintained when they are growing in different environments, and is even expected to increase over time (Eriksson *et al.* 1993).

A typical example of a conservation population capable of evolutionary processes is a protected area in a natural forest. In a protected area, the species occupies its natural habitat (it is said to be *in situ* conserved), typically with a wide range of other species. Natural selection for general fitness is therefore largely related to competition among species, as well as to adaptation within species to current and future environmental conditions. However, evolutionary conservation can also take place in a planted stand, if natural selection is allowed to work, and if the planted trees are regenerated from seed, rather than by vegetative techniques, for the next generation. In such programmes, plantations will preferably be established and managed in ways that mimic the natural processes that will support natural selection. Of course, in most situations the mixture of species (if any) is largely artificial, and the selective forces may therefore favour different genes than would be the case in true *in situ* conservation. However, this reflects the fact that selection and fitness always depend on the degree of human influence in any ecosystem. Directional selection in favour of commercial traits—including characters such as good stem form or ease of establishment in plantations—is typically avoided in strict evolutionary conservation programmes, but of course this again depends upon the local objectives of the programme.

In summary, various factors will influence the success and relative suitability of an *in situ* conservation approach (see Table 2.3).

Table 2.3 Examples of some factors influencing success of *in situ* conservation programmes for targeted tree species at different scales

Factor	Favourable conditions	Constraints
Regeneration conditions	Environment little changed or able to be managed to enable continued regeneration of target tree species	Difficulty in natural regeneration due to altered environment, e.g. climate change; altered flooding regimes, increased salinization; introduced weeds and grazing pressure
Potential for hybridization	Common or abundant tree species with effective mechanisms to minimize interspecific hybridization	Uncommon tree species with propensity to hybridize with related species. Sexually compatible tree species introduced into neighbouring environment
Degree of interdependence on other ecosystem components, in reproduction and dispersal	Area of sufficient size and diversity to support specialized pollinators and animal seed dispersers	Area small or fragmented, and unlikely to support key interdependent faunal elements in the longer term (or animal has already disappeared)
Status of remaining populations of tree species	Viable populations, representing the range of genetic variation present in the species, still extant and capable of management and conservation	Key population(s) have become highly fragmented and/or have approached or dropped below minimum viable population size
Type and level of threats	Threats to survival of populations are able to be identified and minimized through planning and management intervention	Genetically unique populations are at risk from threats which are difficult to control, e.g. new pest or disease, or encroachment
Economic value and utilization by local populations	Tree species is sustainably or non-destructively utilized by local human populations and is locally valued as an economic or other resource	Species has little direct or indirect economic value to local population or land owner/management authority (i.e. species which are valuable genetic resources outside their natural range)
Land use and human population pressures	Species or ecosystem occurs in areas with limited human pressure	Tree populations are found in areas of high pressure on land resources (e.g. high population density; good agricultural land)
Land tenure	Secure, well-defined land tenure	Land tenure unresolved or in dispute
Capacity of relevant authorities to manage and protect designated stands	Protection agencies are competent and well-resourced and able to effectively manage and protect forested areas under their control	Staff in protection agencies inadequately trained and resourced, and unable to effectively manage and protect forested lands
Political and social factors	Political situation is stable	War or civil crisis

As already mentioned, a key characteristic of *in situ* conservation is its dynamic nature and provision for continued evolution in target species. However, *in situ* conservation also implies the avoidance of rapid rates of genetic erosion and of strong directional change of the genetic composition of populations (FAO 1993).

Effective and efficient *in situ* conservation requires a substantial knowledge base (see Chap. 4). In particular, information is needed on factors such as:

- genetic variation in species, and how this is spatially and temporally organized within and among populations
- species dynamics in natural ecosystems, such as reproductive and regeneration capacities of the species of interest, possible interspecific competition, or other processes involved in producing and maintaining variation.

However, in the vast majority of cases, given present technologies and available resources, it is not feasible to directly monitor genetic variation in a particular tree species in a particular area. For the foreseeable future, monitoring of *in situ* conservation of forest genetic resources will need to be focused on basic demographic population studies, for example to determine that adequate population sizes are being maintained through regeneration, as well as some key processes, such as pollination and seed dispersal.

Box 2.3 Conservation of *Eucalytus benthamii*: an endangered eucalypt species from eastern Australia

This case study illustrates the complementary nature of *in situ* and *ex situ* conservation approaches and a strategy for rebuilding the genetic resources of a population that has become fragmented and depleted in numbers.

Eucalyptus benthamii is a tall tree (30–45 m in height) of restricted distribution on fertile river flats in New South Wales, Australia. The species has performed very well in field trials in Argentina, Chile, Uruguay, South Africa and Australia (Mendoza 1983; Lehane 1994; Darrow 1995). It grows rapidly and has displayed an ability to grow on diverse sites, including those subject to frost and drought stress. There is considerable interest in South Africa and parts of South America in developing pulpwood plantations of the species.

Natural distribution and threats

The original habitat for *E. benthamii* was to the south-west of Sydney on the flats of the Nepean river and its tributaries. The species naturally regenerates in areas of disturbed soil following major flooding episodes. Since the arrival of Europeans, most of this habitat has been cleared for agriculture or submerged beneath the waters of the Warragamba Dam (Benson 1985). The species is now found only in two areas in the Hawkesbury–Nepean River catchment.

The larger stand of some 2 000 trees is located in the Kedumba Valley, partly within the Blue Mountains National Park. This area forms part of Sydney's water catchment, and increased future water demands and associated possibility of inundation pose a major threat to the population.

The smaller stand occurs as scattered remnant trees along the Nepean river, including about 100 individuals protected in the Bent Basin State Recreation Reserve. Elsewhere, mature specimens are gradually being lost due to flooding, senescence,

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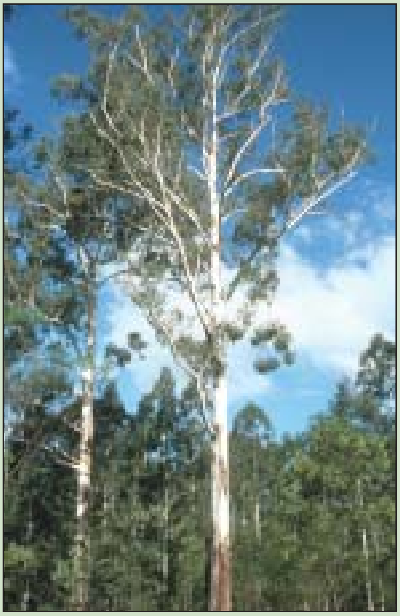
urban encroachment and agricultural development. The long-term viability of these stands is threatened by lack of regeneration associated with poor and erratic seed production and environmental modification, especially increased soil nutrient levels and associated proliferation of introduced weeds.

Conservation measures

The Australian Tree Seed Centre, CSIRO Forestry and Forest Products has been active in conserving and evaluating the genetic resources of *E. benthamii*. The conservation strategy is based on both *ex situ* and *in situ* approaches.

The *ex situ* conservation and evaluation activities include:

- Seed collections from some 100 trees from throughout the natural range of the species, with seed samples placed in long-term (freezer) storage.
- Establishment of gene conservation stands/seedling seed orchards in the Australian Capital Territory (ACT) at Kowen, for the Kedumba population (based on 53 families) and for the Camden–Wallacia population at Yarralumla (based on 25 families). This is a collaborative project with the ACT Forests Department.
- Establishment of seedling seed orchards at three locations near Deniliquin, New South Wales. Each orchard is based on 67–74 families. Development of seed orchards will reduce pressures on the native populations from commercial seed collection.
- Collaboration with local authorities to ensure that *E. benthamii* is widely used in amenity plantings in new urban developments in surrounding areas, near Camden.
- Supply of seed of individual families to South Africa and Uruguay for progeny testing.



Eucalyptus benthamii *in its natural habitat at Kedumba, New South Wales, Australia. (Craig Gardiner/CSIRO)*

CSIRO's activities related to *in situ* conservation have included:

- Submissions to the Sydney Water Supply Department on the effects of raising the level of the Warragamba Dam (including a report on studies by CSIRO on the waterlogging tolerance of the species).
- An information campaign to raise awareness of landholders of the importance of the remaining *E. benthamii* trees on private land.
- Seed from the Camden–Wallacia gene conservation stand is to be used to raise seedlings for replanting within parts of its former natural range to enhance the viability and genetic integrity of this population. The chemical paclobutrozol is to be used in the conservation stand to contain height growth and promote early flowering and seed set.

Many of the natural trees along the Nepean river are isolated or occur in scattered pockets of 1–6 parent trees, and consequently there is limited opportunity for gene

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flow. The gene conservation stand has been designed to maximize outcrossing and hence reduce inbreeding that is probably occurring. The number of parent trees represented in the Camden–Wallacia conservation stand is to be increased over time by using grafting and cutting techniques to propagate isolated trees which do not appear to be producing seed, possibly due to self-pollination and self-incompatibility.

Further specific management interventions needed to regenerate and protect the native Nepean river stands include:

- Encouraging seedling regeneration by surface soil disturbance coupled with elimination of exotic weed species "and"
- Protecting sapling and pole-size trees from fire until they are at least 40 years old. This includes the periodic removal of flood debris from around the base of individual trees to decrease damage from wildfire.

(Based on information provided by C. Gardiner, Australian Tree Seed Centre, CSIRO Forestry and Forest Products, Canberra, Australia)

2.4.3 Evolutionary conservation under use

Evolutionary conservation attempts to maintain genetic processes, so it is relevant to discuss what kind of evolutionary results the selective processes are intended to accomplish. An objective could be to support continued natural adaptations to environmental changes, whether they be through utilization or reflect future conditions for growth. This is possible, and has taken place, for example, during *in situ* conservation of species in the very important managed parklands in West Africa (see Boffa 2000). An extension of this selection pressure by both human and natural forces is where there is an increase in selection on important traits related both to utilization and to a more domesticated plantation system. This then becomes, essentially, an *ex situ* genetic conservation programme as part of a well-designed tree improvement programme (see Vol. 3, Chap. 4).

2.5 Levels of utilization and their effects on genetic conservation objectives

As stated above, conservation of a genetic resource can be set within the context of its possible use and perceived value. A key question, of course, is to what extent utilization and conservation support each other, or work in opposite directions (Kjær and Nathan 2000). In very general terms, one can distinguish three options depending on the degree of integration of conservation and use (see Table 2.4). The three basic strategies are further discussed below.

Table 2.4 Three strategies for conservation based on different levels of integration with use

	Degree of integration and use	Main issues	Strategy
a	Strictly protected areas (hands off)	• Natural gene pool endangered • Natural *resources* are maintained and *genetic processes* are not disturbed by human influence • Compensation to rural people may be required	Complete protection (see Vol. 2, Chap. 4)
b	Sustainable use	• Natural gene pool endangered • The genetic resource is not eroded (the resource recovers) and options for 'harvest' improved as the resource recovers	Sustainable harvest/protection (see Vol. 1, Chap. 3)
c	Increased use	• Natural gene pool of valuable species endangered • Germplasm widely distributed and used • Protection status increased and harvest increased	Increased use through *ex situ* conservation plantings and domestication (tree improvement) (see Vol. 3, Chaps. 4, 5)

(a) utilization is avoided, (b) use is limited to a sustainable level, (c) use is increased

Source: Kjær and Nathan (2000)

a. Strictly protected areas (Table 2.4)

The **hands off** strategy is based on the idea that human influence should be as limited as possible. However, from a practical point of view this strategy is often difficult to implement for at least two reasons (Kjær and Nathan 2000):

- First, existing networks of conserved areas rarely sample the genetic diversity of tree species in a systematic or a genetically representative manner. An example is the *in situ* conservation of forest genetic resources in protected areas in Thailand (see Vol. 2, Box 4.2).
- Second, the hands off strategy works best only in areas where conservation status is already high, generally in places with low population density and where there are no strong economic interests at stake. Establishment of strictly protected areas in areas with high human population pressure is often very difficult.

b. Sustainable use (Table 2.4)

An alternative to establishment of strictly protected areas is to allow use of a given conservation area, but reduce the utilization to a level where the genetic resource is not degraded. In this sense, the idea of **sustainable use** comes from the fact that the genetic resource is conserved *in situ*, but with levels of use that still maintain the genetic integrity of the population. It may be acceptable, for instance, to collect fruit from the trees in the conservation area, but not to an extent where no seed is left for natural regeneration. It may be acceptable to cut down trees, but not to an extent where all straight trees are removed, and so forth.

The sustainable use strategy can apply to the use of target species (priority species in the conservation effort), or associated species. In both cases the impact on the conservation status must be carefully considered (see discussion below). The model of sustainable use of target species can be illustrated by an example from Burkina Faso (see Box 2.4).

The main advantage of the sustainable use model is that reducing the pressure on a particular area or species by limited use can result in long-term recovery of the natural resource, which improves options for future use. In this way, the process can become a self-

Box 2.4 *Acacia senegal* in the Sahel region of Africa

Acacia senegal is a very important species to people in the Sahel region, who among many other things use it for tapping gum arabic. Danida supports an integrated conservation and tree seed procurement programme in Burkina Faso, based at the Centre National de Semences Forestières (CNSF). Conservation of genetic resources of *A. senegal* is one component of this project (see for example Jensen 2000). The Danida Forest Seed Centre (DFSC) has assisted CNSF in developing a conservation plan, which is under implementation. The plan is based on an assessment of conservation requirements based on the distribution and conservation status of the many populations of the species throughout Burkina Faso (Nikiema *et al.* 1997).

Natural stand of Acacia senegal *at Tamasgo, near Kaya, in Burkina Faso. (Lars Graudal/DFSC)*

A number of stands have been identified as potential conservation objects. The management of these stands will be undertaken under a 'joint forest management' scheme, where the stands are managed by local villagers and CNSF to serve local uses (cf. Section 2.2) as well as conservation purposes. Obligations and sharing of benefits among the villages and CNSF are laid down in written agreements following a modality developed by the project, taking local variations in land tenure and user right systems into consideration (Lund 1999). So far, the Burkina experience has shown that the local communities are very interested in this type of collaboration, where there is a clear benefit to them in the short term as well as the longer term (Tapsoba and Ky 1999). The prospects for conservation of genetic resources following this approach are therefore considered to be very promising.

Harvest of gum arabic, near Jebel Dali, Sudan. (Lars Graudal/DFSC, 1986)

reinforcing one, as increased availability of a particular resource makes sustainable harvest easier. Further, this strategy has the advantage that it does not deprive local people of access to important natural resources. A conservation plan may actually provide additional benefits to local people, for instance in terms of legalizing their utilization of a particular resource. Such a strategy can thus be based on true partnership with the local population.

For example, as the discussion in Box 5.2 shows, there is good evidence to assume that resin can easily be tapped from *Pinus merkusii* in a non-destructive way in the Kong Chiam conservation area in northern Thailand. The local users of that area would naturally be interested in legalization of tapping activities and in maintaining the trees, because this is a prerequisite for maintaining their income from harvesting resin from the trees.

From a genetic point of view, it will be a challenge to find utilization patterns that do not erode the genetic resource. Human interventions can affect genetic resources and processes in many ways, and possible implications for conservation of the genetic resources at these levels must therefore also be considered (see for example Namkoong *et al.* 1997). There are complex ecosystems where tree species depend on specific animals for pollination, or depend on very specific ecological conditions (see for example Bawa 1994; Lillesø 1996). These relationships are often not well known, and human intervention can therefore have serious and unpredictable effects on the long-term viability of the population. In such cases, finding a sustainable level of use will be complicated.

Conservation through a sustainable use strategy is straightforward in a social environment where tenure systems and user rights are well defined, although even in these situations a range of technical and social problems will have to be carefully addressed. A 'conservation expert' will often find it easier to recommend a hands off strategy than a sustainable use strategy. However, a combined use and conservation approach may yield far better conservation results than a hands off approach.

c. Increased use (Table 2.4)

Tree species often become rare and endangered because they are in high demand. This is because they provide valuable products such as high-value timber or non-wood products. In such cases, this third strategy could be considered, which involves increasing the degree of human intervention for endangered, ecological or commercial tree species rather than limiting it.

Increased use of genetic resources in terms of plantings in forest areas, watersheds and degraded areas, and on farms, can be a very efficient way of protecting valuable genetic resources. The idea is that cultivation of a valuable but endangered tree species can result in multiplication and distribution of its germplasm. Moreover, when low-density species become common as a result of planting, and their products can be harvested, the pressure on natural populations might decrease. This strategy also has the benefit that cultivation of threatened high-value species actually provides benefit to meet local people's needs for tree products and services, or for cash incomes from sale of tree products (see Box. 2.5).

There is a vast number of tree species that are valuable but are not planted at present. More than 200 important species have been identified in Vietnam alone (FSIV 1996), most of

Box 2.5 *Prunus africana* in Africa

Prunus africana is a tree species native to the African highlands. A medicament used for treatment of benign prostatic hyperplasia is extracted from its bark. The bark is usually harvested by felling trees in natural stands, which has lead to over-exploitation of the species. The species is listed in CITES appendix II regulating trade with endangered species, and all international trade must therefore be under licence. The World Conservation Monitoring Centre has listed the species as vulnerable at the species level, but genetic diversity within the species is probably being adversely affected as well.

The World Agroforestry Centre (ICRAF) has analysed options for conservation of the genetic resources of _Prunus africana_ (see for example Dawson and Were 1999). They find

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Prunus africana seed production stand, *at Muguga, Kenya. Maize and beans grow between trees only for the first year after establishment. (Kirsten Thomsen/DFSC)*

that the species is fairly easy to cultivate on-farm and that the bark from the planted trees can be extracted in a non-destructive way. Cultivating *P. africana* offers the potential of generating income for farmers (the value of the global trade of *P. africana* is approximately US$220 million/year, Dawson and Were 1999). At the same time, on-farm cultivation of this species will be an effective way of protecting its genetic diversity, as well as releasing the pressure on the few remaining natural populations.

which are not currently planted. However, many of the constraints limiting their use are technical in nature, and overcoming them can therefore be a key to the sustainable use and conservation of these species.

Sometimes valuable trees are not planted because of lack of access to germplasm, or problems with seed collection and handling. As mentioned earlier, many tropical species have recalcitrant seed, which means that the seed must be handled with care, and is very difficult to store. Often germination capacity is lost within days (Schmidt 2000). An example of a project that has attempted to overcome these kinds of problems is the Indochina Tree Seed Programme (ITSP) supported by Danida (see Box 2.6).

Box 2.6 Conservation and use of *Dalbergia* species in Indochina

The Indochina Tree Seed Programme (ITSP) collaborates with the Lao People's Democratic Republic Department of Forestry in identifying indigenous priority species in order to include them in planting programmes. *Dalbergia cochinchinensis* is one such priority species found in the Indochina region. As with other *Dalbergia* species, the timber is very valuable (Soerianegara and Lemmens 1994), and has been subject to heavy logging. In Vietnam, *D. cochinchinensis* has been exposed to high rates of exploitation and is considered a threatened species. In Thailand the pressure on the species has also caused concern. The species has been appointed top priority by the FAO Panel of Experts on Forest Genetic Resources (FAO 1999), and is classified as vulnerable by the World Conservation Monitoring Centre.

For a long time, it has been generally assumed that *D. cochinchinensis* trees grow slowly when cultivated. For this reason, it has not been included in planting programmes. However, a demonstration plot in Laos has shown that it can grow quite fast if cultivated under suitable conditions (STRAP 1995). The potential production for this

continued

species is estimated to reach 400 m^3/ha over a 50-year rotation cycle, with a sound silvicultural treatment. The wood is extremely valuable, and the value produced per hectare far exceeds the value produced by, for example, the fast-growing eucalypts or *Acacia mangium*. Planting *D. cochinchinensis* as alternative to the often-planted *Eucalyptus* may provide higher incomes, and protect the genetic resource of the species. In order to provide access to the germplasm, ITSP supports identification of good seed sources, and provides support to genetically broad seed collections from natural populations in collaboration with the provincial authorities. Part of the seed is planned to be used for plantings, which can serve as seed sources for commercial seed procurement later on (Thomsen 2000). Such plantings may form the basis for future domestication of the species in large parts of Laos, and it is therefore very important that at this initial stage seeds are not collected from only a few trees.

Moreover, it is important to raise the general awareness that currently endangered species such as *D. cochinchinensis* can often produce much higher values than presently planted species. Annual value production of US$5 000–7 000/ha is often realistic, about 5–20 times as much as for pines or eucalypts grown at similar sites (Graudal and Kjær 2000).

A 16-year-old stand of Dalbergia cochinchinensis *in Laos, never thinned and probably not going to reach potential production.*
(Ida Theilade/DFSC)

The increased use model can also be effective for tree species that have less valuable products, but are suitable for use in planting programmes connected to land rehabilitation or watershed management programmes. Local species may be suitable for such purposes, because they are adapted to local conditions and may therefore be at less risk from damaging local biotic or abiotic events, provided they are properly planted, tended and managed. Moreover, they will often be suitable for mixed-species plantings where future management may be minimal.

Increased use through domestication involves a series of processes that can have several implications for genetic diversity. First, random as well as intentional selection occurs during seed collection, seed production, nursery culture, planting, tending and harvesting (El-Kassaby and Namkoong 1995). Second, seed and trees can be moved around between ecologically different zones, with increased risks of lack of adaptation and genetic pollution of native resources. This issue, which is not usually considered in plantation programmes, does not guarantee the protection of the genetic resources, unless sound genetic principles are in place and followed. However, if genetic considerations are taken into account, genetic diversity can be effectively protected within domesticated plantings (cf. Namkoong 1984a).

As soon as rural people become involved in planting programmes, a number of additional issues (largely non-genetic in nature) need to be considered:

- First and foremost, rural people must be given the opportunity to identify their own needs, and the planting programmes must respond to these needs. This is important for both the conservation and the ‘development-for-people’ objectives.

- The introduction of new crops should not result in rural people running economic risks that would put their livelihood at stake. Experiments with domestication may be costly, and not all species turn out to be suitable for plantings; the market may be uncertain for new types of products; and it may take 25–30 years before valuable timber or non-wood forest products can be harvested.
- The programme must be organized to ensure that rural people get access to high-quality plant material of threatened species adapted to their localities. A comprehensive discussion on the role of local people and institutional aspects is presented in Chaps. 3 and 5.

2.6 Summary

Development of a case-by-case conservation strategy is usually required. The strategy must address the relevant problems, take into account the available information, identify potential options for actions, and be operationally feasible. It must form the basis for the field activities that can lead to long-term sustainable solutions. However, at the same time, it must be flexible enough to adapt to continuously changing conditions. Nevertheless, a few general considerations may be applicable:

- Clearly defining the objectives, analysing the problem, assessing the importance (priority) and the biology of the species considered (see Section 2.3).
- Evolutionary conservation is usually to be preferred to static conservation (see Section 2.4).
- *In vitro* conservation is seldom useful or economically viable for conservation of forest genetic resources. In unique cases, however, it may be relevant for conservation of species with seed storage problems.
- Seed banks are in general only useful for short-term conservation of forest genetic resources, but can play an important role in this respect.
- Combining conservation with some level of use is often a valuable option:
  – In areas of low population pressure, where the threats are due to logging, it is important to identify ‘non-logged’ or ‘low impact logged’ areas while sampling the ecological variation across the species’ range. In some cases, better management practices may be sufficient. Where the problem is primarily related to heavy population pressure, empowering local communities and awareness programmes and partnerships are extremely important in relation to *in situ* conservation (see Box 2.4).
  – *Ex situ* conservation can be of particular value, if it supports both increased and improved utilization of germplasm with limited access (see Section 2.5 and Vol. 3).
  – Land rehabilitation and the establishment of buffer zones may provide good opportunities to link *in situ* with *ex situ* programmes, and for domestication.

NATIONAL PLANNING

by Lars Graudal, Alvin Yanchuk and Erik Kjær

3.1 Introduction

Developing a national strategy for the conservation of forest genetic resources is an important way of defining and securing appropriate institutional mechanisms for its implementation. The national strategy should also provide general guidelines for planning and implementation of conservation measures and conservation options (*in situ* and *ex situ* over space and time) to achieve the objectives of the programme.

Planning for conservation of forest genetic resources involves the following logical sequence of activities:

- Setting of overall priorities by identifying genetic resources that have priority, usually first at the species level. This should be based on the present or potential socioeconomic value of the species, and their conservation status at important levels in the ecosystem.
- Determination or inference of the general genetic structure of the priority species: for instance, whether they are ecotypic or clinal.
- Assessment of the current level of protection of the target species and their populations.
- Identification of specific conservation requirements or priorities, typically at the population level for single species and at the ecosystem level for groups of species: this involves identifying geographical distribution and number of populations to be conserved.
- Choice of conservation strategies or identification of conservation measures—biological and economic options.
- Organization and planning of specific conservation activities.
- Provision and development of management guidelines.

The setting of priorities deals with the overall objectives of why and for whom genetic resources should be conserved. An important tool in setting priorities is the decision-making framework. Many priority-setting methodologies have been developed and used (see Palmberg-Lerche 2000), and are elaborated upon in Section 3.3 below, but it is critical that the criteria used are important and reflect local conditions.

It is also important to realize that the process of formulating a strategy is iterative and that the strategy itself should be flexible. The scale and complexity of the data needed to meet national conservation and utilization objectives are such that coordination and formulation by a national focal point are required. This is necessary in order to facilitate the collection and processing of relevant data to assist in the planning and implementation of conservation programmes for forest genetic resources by different partners at local, regional, national and international levels. Different combinations of priorities, beneficiaries and relevant partners may require different modalities for planning and implementation. The strategy should identify such different combinations and suggest appropriate implementation arrangements accordingly.

Section 3.2 provides some overall strategic considerations related to the identification of appropriate institutions or groups who should be involved in national gene resource conservation programmes. Sections 3.3–3.9 provide some further elaborations on many of the points listed above. The concluding section of the chapter (3.10) provides a summary of recommendations and overall guidelines related to the development of national gene conservation programmes. A more detailed description of these steps can be found in Graudal *et al.* (1997).

3.2 Identifying appropriate implementation modalities at the national level: strategic considerations

3.2.1 Objectives and organization

The benefits deriving from the use of appropriate genetic material in forestry touch upon many parts of society. Areas where genetic resources of common interest occur may be owned and used by different individuals, communities or public organizations. Interests involved in forest genetic resources are generally many, and the organization of conservation initiatives may therefore be complex.

Furthermore, the distribution of species and ecosystems does not respect national boundaries, and landraces may have developed through utilization and domestication outside the natural distribution area of a species. Conservation of genetic resources in one country may often be of benefit to other countries where the species are presently grown or may have future potential. Therefore, international conservation networks are desirable and the efficiency of national programmes may, in general, be considerably improved through such international collaboration. Nevertheless, from a practical point of view it is necessary initially to develop a national approach, as a basis for international collaboration. This is further discussed in Chap. 6.

An important question to consider in planning genetic resource conservation is the national organizations that are available to carry out the necessary work. First, different public agencies, units and administrative bodies with vested interests in resource management and research may already exist—for example a tree seed centre, a forest service, a forest research institute, a national parks service, an agricultural extension service—and they will likely have the most important stewardship role to play. Second, private sector interests, whether commercial, subsistence or non-profit, may also be present, particularly where other conservation, reforestation or afforestation programmes already operate. These types of existing organizational structures will usually have important roles to play.

Planning should consider the distribution of tasks among existing units, and identify the need for possible new units or structures when necessary. It is also important to consider the economic capacity of the different stakeholders to participate. Participatory aspects are dealt with in detail in Chap. 5, but some overall considerations concerning beneficiaries and implementation are described below.

3.2.2 Beneficiaries and types of interest

The direct beneficiaries of the conservation of forest genetic resources are, of course, the public at large, but more directly and immediately the groups and individuals involved in using the forest. Government authorities, state enterprises, private companies, non-governmental organizations (NGOs) and individual farmers are all stakeholders who may often represent different types of interest:

- Government agencies and authorities—usually the Ministry of Environment and/or Agriculture and Forest Services—typically represent the long-term interests in conserving the genetic resources and biological diversity, and in maintaining the vegetative cover for purposes of environmental protection.

- State enterprises and private companies typically have a direct commercial interest in improved wood production, which is also of national economic interest (through a reduction of import requirements or the generation of jobs in the forestry sector, for example).
- NGOs may have similar interests, but in addition often represent more idealistic objectives of nature conservation by focusing more on intrinsic values.
- The interests of farmers may be commercial or for subsistence, whether in terms of wood fuel, small timber, fodder, food, shelter or environmental protection.

3.2.3 Identifying appropriate implementation modalities at the national level

Conservation of genetic resources generally calls for specialized structures. The specific requirements, in terms of infrastructure and staff, depend on the types and amounts of genetic resources to be handled, and the allocation of tasks among collaborating partners. When considering the organizational structure, it is important to realize that the core activities of genetic resource conservation are to be found in (1) the interface between research and practical application; (2) national long-term conservation interest and commitment; and (3) more immediate commercial and/or subsistence interests.

Vesting the responsibility for conservation within government departments will, in principle, assure independence from commercial interests. It is, however, important to establish close links with seed procurement and storage organizations, whether in the private or the public sector. Likewise, it is important to maintain close links and integration with relevant research (breeding) institutions, whether private or public.

The organizational requirements for the handling of reproductive material differ for different species. In general, representative collections of important species should be vested within an independent national authority. This does not, however, prevent other organizations from contributing to the conservation of genetic resources. The integration of conservation and utilization is important for any programme wishing to exist beyond the short term. The concept of integrating conservation, improvement and seed procurement is the basis of a number of national tree seed and breeding programmes.

The structure of such programmes varies considerably among states and countries, so it is not possible to suggest just one model. Major points to consider in relation to the areas identified for conservation are ownership and associated options, and costs of administration and management. Ownership may influence both the options and the costs of conservation. On private land, for instance, the opportunity costs of *in situ* conservation may be prohibitive if alternative land use is profitable. In some cases the conservation of genetic resources may be considered free of additional cost, if the resources are already protected for other purposes.

3.3 Overall priority-setting: selection of species to be conserved

The main criterion for including species in genetic resource conservation programmes is their present and possible future value. The identification of genetic resources of priority is thus, in principle, a cost–benefit consideration. Ideally, cost–benefit analyses require quantification of the values associated with a given species or population and the risks attached to the results of different management options. Very often such quantification is not possible, particularly when considering potential value.

Considering the thousands of forest tree species and their distribution in an even larger number of populations, the critical issues in gene conservation planning are (1) how best to identify species to be included and then (2) how to select the populations to be conserved. There are different but complementary criteria that can be considered in setting priorities:

- Current local importance, even if the species currently contribute only little to the economy (perhaps because they are rare).
- Economic value, such as in species that may be of major importance for the subsistence of local populations in rural areas.
- Ecological and geographic considerations, such as status in typical stands (whether common or rare), geographic range (in one or more countries), and capacity for natural regeneration, to mention a few.
- The current conservation status of species and their populations (see Section 3.5) may be used as an indicator for prioritization. For example, the current level of protection in protected areas (*in situ*), and in breeding or research programmes, should be part of the priority-setting process. If the conservation status is good, there may be little need for further action.

Several more thorough priority-setting approaches have been developed and described (see for example Franzel *et al*. 1996; Yanchuk and Lester 1996; Koshy *et al.* 2002), but any particular suite of criteria that is ultimately chosen to rank species for conservation activities needs to consider local conditions and factors. Priority-setting processes can of course consider factors as equally important, or differentiate them by weighting the criteria. The net results of the priority analysis and weighting system ultimately used must make logical sense.

3.4 Assessment of genetic variation: determination or inference of the genetic structure of species

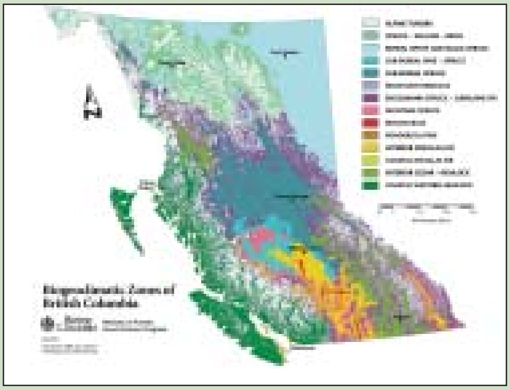
In gene resource conservation, after species-level decisions are made, it is the population level that we are really interested in conserving. In practice, as the term 'gene conservation' implies, genes are the resource we want to conserve, as we consider all genes to be potentially useful. However, it is ultimately genetic variation and the processes that contribute to the maintenance of genetic variation that we hope to conserve, and only by conserving targeted populations can we accomplish this.

Reliable information on the distribution of genetic variation—within and between geographic regions—is important in order to establish an effective network of conservation populations. Genetic variation can be assessed by different techniques. It is possible to study morphological and metric characters in field trials, or with biochemical and molecular markers using laboratory techniques. However, both field trials and laboratory studies are expensive and time consuming. Without genetic data and information, the conservation officer is almost always forced to assume that the patterns of genetic variation in the species will follow some if not all of the patterns of ecogeographic variation. This is not always true, but it is a safe and conservative assumption in most cases. The role of research, and the kind of genetic studies that are likely to contribute important information and thereby assist in improving conservation efforts, are discussed in more detail in Chap. 4.

As mentioned above, when little genetic information on population structure is available, we must rely on an assessment of the ecogeographic variation in the distribution area of interest. The approach typically considered can be referred to as **genecological zonation**. A genecological zone can be defined as an area with sufficiently uniform ecological conditions to assume similar phenotypic or genetic characters within a species. Such zonation also assumes there are some limits to extensive gene flow, which could offset local

Box 3.1 Stratification by ecological zonation for *in situ* FGR in B.C., Canada

Patterns of genetic variation are well known for only a few species in British Columbia, so some stratification of the province was required to accommodate the large ecological variation for many other species that have not been investigated for genecological variation. Initially, **ecoregions** were used to stratify the province as they represented broad ecologically similar areas, and met most of the concerns relating to large differences in latitude and longitude (Yanchuk and Lester 1996). To accommodate expected genetic variation due to climatic differences caused by elevation and prevailing climate affected by mountain ranges, a further ecological stratification was imposed. **Biogeoclimatic (BEC) zones** were therefore overlaid on the ecoregions to address elevational differences. BEC zones could have been used alone, but, judging from our experience of patterns of genetic variation in other species, some of the larger zones spanned too many degrees of latitude (and longitude). Species ranges were overlaid on this stratification strategy, and choices were then made as to which of the ecoregion/BEC combinations would be critical to cover expected genetic variations in 23 of the conifer species being studied. Further criteria were used to determine how adequate *in situ* conservation may be in each of the ecoregion/BEC overlays, after evaluating the relevance, number and quality of the protected areas (Yanchuk and Lester 1996). This stratification approach was one of many ways in which ecological zonation could be developed to help cover genetic variations that may be present without having a detailed knowledge of genetic variation in the species under conservation.



Stratification by ecological zonation for in situ *conservation of forest tree genetic resources in British Columbia, Canada (Alvin Yanchuk/B.C. Ministry of Forests).*

A more advanced approach is now being developed that will accommodate the evolving and dynamic nature of *in situ* reserves, new genetic information and changes in climate. The use of geographic information systems (GIS), the use of zonations that are based on details of genetic variation, and conservation and breeding units are now being developed (Hamann *et al.* 2004). The use of more modern computer and mapping technology will allow for a more dynamic management system, which may be able to accommodate changes in conservation objectives. These objectives may change as we obtain more information on patterns of genetic variation in individual species and as climatic, social and economic goals (such as the collection and management of breeding or *ex situ* management) also change. These principles of ecological stratification, combined with newer GIS capabilities, can be a powerful means for planning for gene conservation or breeding units, in all types of species.

(Provided by A. Yanchuk)

adaptations to local environmental and ecological selection pressures. Factors typically considered for zonation are natural vegetation, topography, climate and soil, as well as barriers to the dispersal of pollen and seed.

3.5 Assessment of conservation status

Conservation status refers to the present state of the genetic resources and immediate risks to them. Questions to examine may be:

- Are potentially important populations at high risk?

Box 3.2 Conservation status of *Baikiaea plurijuga* in Zambia

As a result of logging and clearing of land for agriculture and frequent fires, Zambezi teak (*Baikiaea plurijuga*) forests are threatened throughout most of their range. In order to conserve the genetic resource of the species, a sufficient number of populations must be protected. The aim of this particular study was to identify a number of populations from different parts of the distribution of teak in Zambia to be protected and managed in order to conserve the genetic variation within the species.

In situ *conservation stand of Zambesi teak (*Baikiaea plurijuga*), Malavwe Botanical Reserve, Zambia. (Alan Breum Larsen/DFSC)*

The method of ecological zonation was considered to be a simple, fast and relatively cheap tool for determining conservation measures, as it was largely based on information that was already available. For instance, some of the remaining *Baikiaea* forests are within existing national parks and are thus assured some level of protection. Although no genetic studies have been carried out on Zambezi teak, we have some knowledge of its ecogeographic variation. The occurrence of Zambezi teak is closely linked to the Kalahari sands throughout its whole distribution, and there are no other distinct topographic features that could act as barriers to gene flow. Therefore, the main ecological zonation is based on patterns of rainfall, the existing agroecological zone and the distance between separated Zambezi teak forests.

Based on the three agroecological regions and the nine agroecological zones where *B. plurijuga* is found, a genecological zonation was drafted. From this, seven genecological zones were proposed, which differed from the agroecological zones primarily in terms of the proximity of stands to each other. Boundaries were drawn up so that separation of continuous forest areas was avoided. For each of the seven sites, a description of site or 'reserve' history, area of the site, current conservation status, assessment of threats and recommendations for conservation have been developed. See Vol. 2, Box 4.5 for more on teak in Zambia.

Source: Theilade *et al.* (2002)

- How well protected are remaining populations?
- Do protected remaining populations adequately cover geographic, ecological or genetic variants where the species occurs?
- What are the future trends or risks (harvesting, climate change, etc.)?

These questions have to be addressed using the best available information on:
- past and present geographical distribution
- prevailing utilization patterns in terms of direct use in the form of harvesting, planting and breeding of the species (including introduction of intercrossing species/ provenances) or indirectly through changing land-use patterns
- likely occurrence in currently protected areas.

3.6 Specific priority-setting: identification of populations to be conserved

By comparing the genecological zones and the distribution of the species of interest, it is in principle possible to identify the number of areas and populations that should be protected or sampled for conservation. It would be desirable to conserve all major variations in the gene pool, but the number of conservation stands needed must be set at a manageable level.

In practice, the comparison of genecological distribution and conservation status consists of several steps:

1 Overlay genecological zones with:
- the natural (past) and present geographical distribution of the species
- the occurrence of the species in ongoing planting programmes (*ex situ* status) and protected areas (*in situ* status)
- location of provenances that are known to be valuable.

2 Consider other factors that may affect the maintenance or structure of genetic variation, conservation status, and the conservation investment requirements, for example:
- variation in the forest types across the distribution (for example natural successional variation, regeneration rates, densities in different forest types)
- reproductive biology and dispersal capabilities (as they may affect inbreeding levels or gene flow through seed and pollen)
- size and geographical location of past and ongoing planting programmes, and origin of the planting material used
- safety and management requirements of various *in situ* and *ex situ* investments
- land tenure and associated options and costs.

3 Decide on appropriate geographical or genecological representation, the number of areas per zone, and the number of populations or stands to be conserved or sampled in each area:
- For species with particularly scattered distributions, the size, frequency and proximity of identified groups of trees needs to be considered, to attain an adequate level of sampling (see Vol. 3, Chap. 3).
- A programme where many species are targeted at the same time offers the possibility of taking ecosystem dependencies among species into consideration,as well as rationalizing areas sampled in order to save costs. More detailed information on identifying *in situ* conservation stands is presented in Vol. 2.

Box 3.3 A systematic approach to conservation of FGR in Denmark

In the early 1990s a systematic strategy for conservation of the genetic resources of trees and shrubs was developed for Denmark (Graudal *et al*. 1995). The strategy covers 75 species of actual or potential use for planting in Denmark. Its objective is to conserve genetic variation in each species so as to ensure their adaptability to environmental change and maintain opportunities for tree improvement.

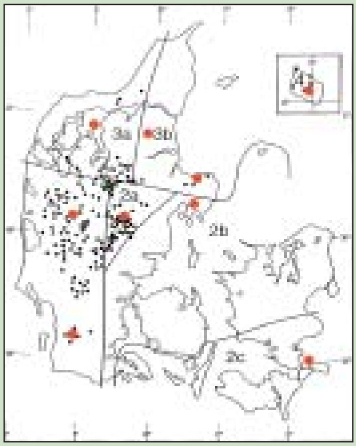
The plan is for the genetic resources to be conserved in evolutionary conservation stands, both *in situ* and *ex situ*. The identification, monitoring and management of the network of gene conservation stands will be carried out by the Tree Improvement Station of the National Forest and Nature Agency.

Selection of conservation stands

We have only a limited detailed knowledge of the genetic structure of most species in Denmark. A survey based on ecological data and genetic information from biochemical marker studies and field trials currently provides the best basis for the selection of populations for conservation. This approach has been used for better-studied species such as *Quercus robur*, *Q. petrea*, and *Fagus sylvatica*. For most species the selection of conservation stands was based on an assumed genecological variability. The estimated number and distribution of conservation stands was determined using the following information:

- natural distribution of the species
- biology of the particular species, especially mode of reproduction and origin
- a preliminary genecological zonation for Denmark.

The zonation was based on a compromise between the variation in ecological factors and expectations of gene flow, as selection differences resulting in environmental heterogeneity can result in local adaptation only if the barriers to gene flow are sufficient (see Jacobsen 1976; Nordisk Ministerråd 1984; Ødum 1987). The four main zones, of which two are divided into subzones, are shown in the figure. The validity of the preliminary genecological zonation will be tested by classification of environments based on existing provenance trials with special emphasis on adaptive traits, and by isozyme studies on the variation for selected species within and between the zones.



Tentative genecological zonation of Denmark and the natural distribution of Quercus petraea. *(DFSC)*

For each species, between 2 and 15 conservation stands were considered adequate to conserve the species' genetic variation in Denmark. For the 75 species, a total of 600 stands is required, 500 of them *in situ*, totalling 1 800 ha, excluding isolation zones. This corresponds to 0.4% of the total forest area in Denmark, but 5% of the remaining area of natural forest.

continued

The design and management of each stand will be registered in management protocols. Management prescriptions will vary with species and the site-specific characteristics of each stand. General guidelines for the design and management of individual conservation stands are given in Graudal *et al*. (1997).

The tentative genecological zonation of Denmark (after Graudal *et al.* 1995) and the natural distribution of one species, sessile oak (*Q. petraea*) according to Ødum (1968) are shown in the figure. Dots represent findings according to the literature, flora lists or herbarium material. Nine nominated conservation stands covering the genecological variation are ringed in red.

3.7 Selection of conservation strategies: identification of appropriate conservation measures

When specific populations have been identified for conservation, the next step is to decide which conservation measures to apply. The types of questions that must be answered are:

- Should a given population be physically demarcated and guarded in the field?
- Should reproductive material be collected and stored in some *ex situ* vehicle?
- Should a population be strictly protected, or can we combine its conservation with some form of use, such as harvesting bark, seed or wood?

As mentioned in Chap. 2, it is generally preferable to conserve forest genetic resources by maintaining the potential for evolutionary processes to continue in designated conservation populations, in the form of living stands, preferably *in situ*. *Ex situ* conservation with some evolutionary potential can also be considered. For economic reasons and when evaluating security, *ex situ* conservation or some combination of *in situ* and *ex situ* methods will usually be considered. *In situ* and *ex situ* conservation are dealt with in more detail in Vol. 2 and Vol. 3, respectively.

3.8 Organization and planning of specific conservation activities

As mentioned in Sections 3.1 and 3.2, when planning a genetic resource conservation programme it is important to consider:

- who is providing the ownership and stewardship of the programme at the national and international levels
- what may happen in practice.

Administrative and research units working in the public sector need to ascertain that all interests are considered. When populations and conservation measures have been identified, a number of field activities will follow:

- field survey to verify the selection of conservation stands
- demarcation, guarding, tending and monitoring of *in situ* conservation stands
- collection, extraction, storage and multiplication of reproductive material for *ex situ* conservation.

Once again, these activities are described in more detail in Vol. 2 and Vol. 3 for *in situ* and *ex situ* conservation respectively.

3.9 Preparation of management guidelines for the objects of conservation

For successful management and documentation, conservation measures need to be described and monitored through the use of specific technical guidelines. From a management point of view it is useful to distinguish between two major groups of conservation methods: conservation stands (either *in situ* or *ex situ*) and genebanks (*ex situ*).

3.9.1 Conservation stands

The need for management and the specific management interventions will vary with species- and site-specific characteristics of each stand. A conservation stand can be either a **pure stand** consisting of one species or a **mixed stand** of several species. In a mixed stand, one or several species may be targeted for gene conservation. The stand can be established artificially (planted or sown), or through regeneration (natural or assisted by silvicultural interventions). Artificially established stands are typically considered *ex situ* stands and naturally regenerated stands are often considered *in situ*. General management prescriptions for *in situ* and *ex situ* conservation stands are often similar; the main differences relate to the fact that *ex situ* stands are planted, with more control of species and stocking levels.

More detailed sampling and management considerations are provided in Vol. 2, Chap. 2 and Vol. 3, Chap. 3. A brief summary is provided here.

Number of individuals

- Mixed stands where the objective is to conserve the genetic variation of one or more species will in general have to be larger than pure single species stands.
- A very conservative ‘rule of thumb’ estimate for an *in situ* stand, for a wind-pollinated species, should initially contain at least 150 and preferably more than 500 interbreeding individuals of each of the targeted species.
- In terms of conservation of quantitative genetic variation, about 150 individuals will capture approximately 99.7% of the variation present in the initial population. Several hundred individuals are typically considered necessary to capture more of the lower-frequency genes (Yanchuk 2001).
- For populations expected to receive little or no management, larger numbers of individuals should be considered, because of random events and demographic factors which are affected by differences and natural variations in the basic biology of the species.
- The actual numbers of individuals targeted for conservation within a population should be determined by examining the costs of maintaining more individuals, in relation to the benefits of capturing more genetic variation. This topic is dealt with in more detail in Vol. 2, Section 2.3, and in Vol. 3, Chap. 3.

Regeneration and isolation

- For *in situ* populations, the conservation stands should be regenerated with genetic material originating from the same or adjacent stands, with as little genetic influence as possible from outside (in the form of contamination by pollen from external sources).
- In practice this requires some type of isolation. This will depend greatly on the reproductive biology of the species, but isolation belts of 300–500 m are generally considered adequate for most wind-pollinated species.

Tending

- The need for tending depends on species and site conditions. When it is required, it should favour regeneration and stability of trees and stands.
- For some populations it may be necessary to consider special management systems, which may include cutting of competitive (invasive) species, or—for certain bushes—controlled animal grazing or fire.
- Thinning is generally considered the most important tending intervention, in particular where it stimulates regeneration. In pure stands systematic thinning is usually recommended in order to maintain the current genetic constitution of the stand (in other words, high-grading is not allowed).

Utilization

- In some cases, the conservation effort can be combined with different forms of forest utilization, if the use does not change the genetic constitution of the stands, as mentioned above.

Site conditions

- For both *in situ* and *ex situ* conservation in the field, site conditions and quality are of course an important consideration. Site selection and management for *ex situ* stand conservation is dealt with in more detail in Vol. 3, Chap. 5; however, site quality and many other factors also need to be considered during the selection of *in situ* stands. The long-term conservation status of both *in situ* and *ex situ* stands also needs to be taken into consideration (for instance, the life expectancy of a healthy proportion of trees in the population).

3.9.2 Genebanks

Ex situ conservation of forest genetic resources in genebanks is a potentially important complementary measure to the use of conservation stands in the field.

The term ‘genebank’ may imply a need for expensive and modern technology, but this is not necessarily the case. Fairly simple storage facilities, which are quite widely available, can be used for *ex situ* conservation of many species. More specialized structures may be required in some cases and may only be available at the international level. Documentation requirements and methodology are in principle the same, with more detail provided in Vol. 3, Chap. 6.

3.10 Summary

Recommendations relating to the development of a national forest genetic resources programme can be summarized as follows:

- Countries with significant forest resources need to consider developing a national strategy for the conservation of forest genetic resources.
- The national strategy needs to be elaborated in accordance with perceived and known international and national needs, as well as institutional and financial capabilities.

The elements of the strategy should include:

- objectives
- list of target species
- agencies and organizations (partners) to be involved
- mechanisms for facilitating collaboration between partners
- distribution of tasks among partners

- provision of general management guidelines
- identification of relevant international collaboration.

The strategy should be followed by species specific action planning:
- assessment of genetic/genecological variation
- assessment of conservation status of the target species and their populations
- identification of conservation requirements and priorities at population and ecosystem levels
- identification of appropriate conservation measures
- identification of implementing partners and preparation of agreements for implementation
- provision of specific guidelines for management and monitoring.

RESEARCH NEEDS

by Weber Amaral, Erik Kjær, Alvin Yanchuk and Lars Graudal

4.1 Introduction

For most tree species, especially for many important tropical species, we have only a limited knowledge even of basic biology. Considering that there are thousands of tree species with current and future economic potential, it seems impossible for us to make anything more than qualified guesses about their basic biology and genetic structure. Our dilemma is that we recognize an urgent need for conservation without really knowing what to conserve!

The importance of research in order to fill this enormous information gap is often stressed, but it may not be the best use of the limited resources available. In fact, research is expensive, time consuming, and often limited to relatively few species and their populations. The key question associated with the initiation of field conservation activities is, therefore, what kinds of genetic studies are likely to contribute important information, and thereby assist in improving conservation efforts. We need to set priorities and identify strategic actions that will have a high impact.

4.2 Relevance of specific studies for practical conservation programmes

There are a number of problems that must be addressed in most conservation plans, once priorities have been set. Research activities have the potential to support the decision-making process, especially in relation to the following questions:

- Where are the remaining trees/populations of the target species located, and what is their conservation status?
- How many gene conservation populations are required (one, a few or several)?
- Which populations (locations) should be conserved (or form the basis for seed collection to be *ex situ* conserved)?
- How large should conservation units be?
- How should the conserved areas be managed?
- How can the trees be propagated for *ex situ* conservation?
- How are the species used at present and how can use and conservation be combined?

Studies that can increase the likelihood of making 'right decisions'—the design and implementation of successful conservation programmes—should be considered as a part of the overall activities. Although there are many basic biological and genetic processes that it would be valuable to understand in more detail, these questions are generally best left to research programmes with longer-term funding that can address more basic biological research.

In order to have practical impact on a specific gene conservation effort:

- The study should be economically and technically feasible in a practical context. There are too many poorly investigated tree species, and only limited resources available for overall conservation efforts, so resources must be wisely used.

- The results must become available in good time. Often there is an urgent need for action, and many of the initial decisions often have to be taken within a few years.
- Any new information must be expected to have an impact on the way that conservation activities will be planned and implemented; in other words, it must increase the likelihood of the conservation programme's success.

Below we discuss what kinds of research programmes can shed light on key questions and at the same time fulfil the requirements of being relevant, economical and quickly done. In the longer run, the knowledge gained can be utilized in several ways to build a more complex understanding and description of genetic variations in a species. Still, in a specific situation the decision often has to be made to allocate limited funds either for a number of interesting applied research programmes or for field conservation activities. Collection of information and initiation of research and development activities are, therefore, considered below in the light of the limited resources available for specific conservation programmes. A more comprehensive discussion of the role of research in gene conservation programmes can be found in FAO (2002).

4.3 Where are the remaining populations, and what is the conservation status of the targeted species?

On the basis of our knowledge of dramatic loss of habitat, thousands of tropical tree species are listed as endangered in the 'red list' of threatened species (IUCN 2003), accompanied by notes on distribution and threats. When it comes to elaborating on conservation plans for particular species, however, our knowledge of their occurrence, frequency, ecology and status is often insufficient. In most cases it is necessary to undertake at least some basic surveys to locate the remaining populations, estimate population numbers, study population dynamics and monitor threats. If the aim is conservation of species and representative ecosystems for the species, surveys provide baseline information against which changes can be monitored.

Before new surveys are designed, available records from forest departments, herbaria trade records or specialist groups should be retrieved. Specialist groups could be foresters with field experience in a particular area, botanists or contractors using the resource. Very often indigenous or local people have detailed local knowledge of the distribution and abundance of a given tree species.

Once the basic information has been gathered, a standardized sampling methodology for the research activities can be developed. A number of different sampling techniques are available, and it is important to use suitable methods to make the effort that goes into the data collection worthwhile. The method chosen will depend on the habit of the species. Does it grow scattered or in clumps? Is it a dominant species forming uniform stands or a habitat specialist? In some situations, particularly in the tropics, trees of the same species are scattered far apart, and this has to be reflected in the sampling technique. For further information on inventory techniques, the comprehensive literature, such as that provided in Hyppa *et al.* (1998), should be consulted.

Demographic surveys are the basis of any conservation programme on threatened tree species. Recording habitat information will probably advance our knowledge of the habitat preference of species where this information is lacking or poorly understood, as the case is for many rare tropical trees. Observations on the general ecology of a species are often of great importance to efforts to conserve it. For example, a species might be protected, but if key associates such as pollinators or animals that disperse seeds are lost, the conservation efforts are likely to fail.

Once information from the field surveys is collected, it is still not easy to 'convert' these data to a known conservation status. There are many factors that influence conservation status (see Chap. 3), but any system that is used to weight these factors, and finally end up with some priority list for conservation, will also probably need to address the question of how much is known about the reproductive biology and the genetic structure of the species. For species of high to middling importance, a 'gap analysis' of what is known would be the first activity to carry out in order to decide what research activities should be considered.

Ironic as it may seem, genetic information as such may not be absolutely required to meet most of these objectives. Even without genetic studies, which generally provide information on genetic variation within and among populations, we can be reasonably sure that there is some genetic variation and it will be partitioned at some level as variation either within or among populations. If we are interested in conserving what is there, then the amount itself does not matter much to our conservation objective. So we must always attempt to sample at the population level and with good representation of individuals within the chosen populations.

Also, gene conservation is largely a problem of conserving lower-frequency alleles, and ensuring the presence of evolutionary processes that create and maintain these genetic variations. However, we can never really monitor these closely, and are obliged to estimate their presence by theoretical means. For example, although a well-designed molecular genetic marker study could greatly elucidate the distribution of neutral alleles (providing estimates on within- and among-population genetic variation, outcrossing rates, heterozygosity and gene flow, for example), the magnitudes of these population genetic parameters may have only a relatively small effect on the final decisions a conservation officer may be forced to make in the field. Therefore, although such detailed studies have great confirmation value, and may even optimize sampling approaches (see Vol. 3, Box 3.3), they may not be the most effective use of research capacity or funding.

4.4 Research to assist with decisions on conserving populations

For most species, genetic variation among populations is rarely known before gene conservation efforts are initiated. Most of the targeted species often grow under variable ecological conditions, and/or cover a large distribution area. This suggests that it may be desirable to conserve a large number of populations representing different parts of the distribution area. However, there normally is a limit on how many populations can be handled efficiently. The question is, therefore, do populations actually differ, by how much, and in which attributes? The smaller the population differences, the fewer populations need to be included in an effective conservation programme.

In general it is advisable to assume, particularly for forest tree species which have been exposed to different selective forces (such as drought or cold tolerance) over long periods of time, that populations may have developed genetic differences due to natural selection. Also, genetic differences can be generated between small populations that have been genetically isolated from each other for a long time, and different histories of introduction and migration can also lead to populations that are genetically different (by genetic drift, for instance). A number (a 'network') of different populations should then be conserved, rather than just a single larger population. Still, not all populations can be conserved, and the question is then *how many* populations need to be conserved, and—once the size of the network is determined—*which* populations should be conserved?

Provenance trials are still the most common and informative technique for studying genetic patterns, using quantitative traits such as survival, height, diameter, stem form and fruiting/flowering. More recently, a number of studies based on DNA genetic markers have emerged and developed rapidly, and now allow fast surveys of genetic variation within and between populations (see Box 4.1) (also see for example Gillet 1999).

Box 4.1 Molecular markers and forest tree species

Tree species are, in general, undomesticated plants (with a few exceptions used in forestry and agroforestry practice, such as species of *Eucalyptus, Pinus, Populus* and *Prunus*). For most other tree species, basic information on reproductive biology, geographical distribution, breeding systems and genetic structure is either missing or scant. Recently, molecular genetics and other biotechnological tools have been used more intensively to answer some of these questions (Boshier 2000; Hamrick and Nason 2000). These tools have also been applied to industrially important species (Jain and Ishii 2003), using plant cell and tissue culture techniques.

This general direction is being confirmed by the use of state-of-the-art markers, such as microsatellite markers or simple sequence repeat (SSRs), to assess genetic diversity levels for several tree species. Tree species from which SSRs have been found are listed in Table 4.1, and genetic studies are being conducted using these markers.

The main areas where SSR markers are being applied in forest trees include studies of genetic diversity in natural and breeding populations (particularly in species with low levels of isozyme variation), gene flow, pollen and/or seed dispersal and mating systems. As these parameters are relevant to the conservation of forest genetic resources, SSRs are being used to monitor genetic impacts of forest management practices and population fragmentation (Young and Boyle 2000). In domestication programmes, microsatellites can also be used for germplasm identification, and to assist with the construction of genetic linkage maps, with the eventual goal of performing marker-assisted selection (MAS) in most studied tree species of *Populus*, *Pinus* and *Eucalyptus*.

Table 4.1 SSRs found in tree species, and their application

Species	Number of loci	Application	Species	Number of loci	Application
Acacia mangium	10	Genetic diversity	*Pinus strobus*	23	Genetic diversity
Dryobalanops lanceolata	10	Genetic diversity	*Pinus contorta*	5	Genetic diversity
Eucalyptus nitens	4	Genetic conservation	*Picea abies*	7	Genetic diversity
Eucalyptus grandis	20	Breeding/mapping	*Picea sitchensis*	7	Genetic diversity
Eucalyptus sieberi	10	Genetic conservation	*Pithecellobium elegans*	15	Gene flow
Eucalyptus globulus	25	Breeding	*Populus tremuloides*	20	Genetic diversity
Fagus crenata	9	Genetic diversity	*Quercus macrocarpa*	15	Genetic diversity
Grevillea macleayana	7	Genetic diversity	*Quercus myrsinifolia*	9	Genetic diversity
Gliricidia sepium	4	Gene flow	*Quercus petraea*	17	Genetic diversity
Melaleuca alternifolia	102	Genetic structure	*Shorea curtissii*	9	Genetic diversity
Pinus radiata	24	Mapping	*Symphonia globulifera*	10	Genetic diversity
Pinus sylvestris	20	Genetic diversity	*Swietenia humilis*	13	Genetic diversity

Adapted from Butcher *et al.* (1999)

Box 4.2 Different patterns of genetic variation in *Pinus contorta* in B.C., Canada

Pinus contorta is widely distributed in North America, and is one of the most economically important species in western Canada. It has been extensively studied using both molecular markers and quantitative genetic characters, with most of these being provided by several of the tree improvement programmes that are under way in this species. In one study, a comparison of the differences in genetic variation obtained from molecular markers (usually assumed to be neutral genetic variation) versus metric traits for *P. contorta* in British Columbia, showed that over 90% of isozyme variation resided within populations, even though populations cover a large geographic area in the province (Yang *et al.* 1996). Near complete outcrossing and extensive gene flow were expected to be the main forces maintaining low levels of genetic variation among populations. However, comparisons of Fst (now more commonly referred to as Qst) statistics (fixation indices) from quantitative traits, and Fst from isozymes, made it possible to work out whether similar evolutionary processes were involved in morphological and isozyme differentiation in *P. contorta* var *latifolia*. The results indicated that patterns of differentiation for branch angle and branch diameter were indistinguishable from those expected under the neutral hypothesis (no or limited selection, or simply random genetic drift); however, populations were statistically differentiated for wood specific gravity, stem diameter, stem height and branch length. This suggests that selective forces have been working on this later suite of traits, whereas non-selective forces such as genetic drift and gene flow have probably played a significant role in governing the level of population differentiation in the former (as measured by branch angle, branch diameter and isozymes).

Provenance trial of Pinus contorta *var.* latifolia*, in British Columbia, Canada. (Alvin Yanchuk/B.C. Ministry of Forests)*

These results show that careful consideration must be given to the type of trait being measured (genetic markers which are expected to be neutral versus quantitative traits which may be under selective forces), before the conservation officer or forest geneticist makes decisions on how to allocate resources among and within populations for conservation. Although neutral genetic markers such as isozymes can be used to outline patterns of variation that may be linked to important adaptive characteristics, their value is generally greatest for looking at historic patterns of migration, genetic distances and gene flow which may have other attributes that are important in the design of a conservation programme.

Source: provided by A. Yanchuk, from Yang *et al.* (1996)

However, it is important to note that, for a given tree species, different traits can exhibit quite different genetic differentiation patterns. This has been shown, for example, for *Pinus contorta* (Yang *et al.* 1996) (see Box 4.2) and *Pinus sylvestris* (Karku *et al.* 1996).

As indicated in the above example for *P. contorta*, observed genetic patterns of variation are the outcome of interactions between evolutionary forces: small population sizes (genetic drift), mutation, migration and natural selection. In particular, natural selection has different impacts on different traits: some are strongly selected because they relate to the fitness of the individuals, whereas others may be much more weakly selected, may be correlated to other traits, or may have no selective or correlated responses at all. In very general terms one can distinguish the following:

- **Quantitative traits subject to strong natural selection:** genetic variation for quantitative traits such as survival, growth (height, diameter or volume) or phenology (flushing date or date for termination of growth) is expected to be highly influenced by natural selection. Adaptation to different ecological conditions can therefore be expected to be responsible for important differentiation between populations for species that grow naturally in a large area with varying climatic conditions. This is in accordance with many provenance trials for a large number of tree species, which have revealed important variation between populations in growth and survival.
- **Neutral traits:** the variation pattern for selectively neutral markers (allozymes or DNA markers) is believed to be a result of genetic drift and migration only, as they are neutral with respect to natural selection. In trees, most studies of genetic variation in neutral markers have shown limited differentiation between populations (Hamrick and Godt 1990; Hamrick 1994).

In summary, it is important to note that because genetic markers and common garden experiments assess different types of genes, the outcome in terms of estimates of genetic differentiation will also be different. For practical purposes, the first priority for research is to examine variation in fitness-related traits rather than results from genetic marker studies such as allozymes, or DNA markers (for examples, see Chap. 2, Table 2.2). However, genetic marker studies are typically cheaper and simpler to do, can provide good basic background information on population structure (see Vol. 3, Box 3.3) and can affect decisions on sampling approaches.

Studies on performance under controlled conditions, such as drought stress in nurseries, may be an important supplement to classical long-term provenance testing in the field. However, provenance trials (and most quantitative genetic studies) have some drawbacks:

- Results will not become available for a number of years. Trials are normally evaluated long before the trees are mature, and thus exclude information on variation that appears fairly late in the life cycle. However, early test information in well-designed field trials can yield important information on growth potential among populations (phenology or growth rhythm, for example).
- Results from a given set of trials basically reflect growth under the given conditions. Other trial sites may yield other results, so it is usually wise to include 2–4 test sites per experiment, with contrasting climatic or edaphic conditions.

To conclude, studies based on genetic markers should be used with care unless they are combined with observations on quantitative traits such as growth and survival. Genetic marker studies offer potential information on relations between populations that have been generated by restricted gene flow between small populations, or as a result of different migration routes. Such information can be considered as useful background when interpreting the results from field trials. Also, general levels of inbreeding and genetic diversity can be estimated from molecular marker data. However, such data generally do not reveal differentiation in the fitness-related traits, which is a serious drawback, because it is these traits that are normally the most important when it comes to designing gene conservation programmes.

4.5 How large should conservation units be?

Much attention has been paid to genetic processes associated with small population sizes. It is well known that conservation units should not be too small, as this will cause continuous loss of genetic diversity by the effects of genetic drift and increases in inbreeding. Considering various aspects of these processes has led to a number of recommendations for the required effective number of trees that should be included in a conservation population.

The actual population sizes that are required for specific conservation objectives are dealt with in more detail in Vol. 2 for *in situ* conservation and Vol. 3 for *ex situ* conservation. Briefly, however, much of the literature on the topic suggests that population sizes could vary from 50 to as large as 5 000, of course depending upon the actual conservation objectives. As mentioned earlier, at the lower end of this range (50+) the target tends to be quantitative genetic variation (*ex situ* objectives), and trying to conserve the most basic levels of genetic variation at our disposal. At the higher end of the range (in the thousands) the target tends to be lower-frequency genes, as well as the maintenance of quantitative genetic variation accounting for a balance between drift and mutation mostly in natural populations (*in situ* objectives).

From a practical point of view, having a target of 5 000 rather than 50 trees can create a substantially different conservation approach. Can research assist in deciding the required number more accurately? Different genetic approaches can be applied to guide the decision on the required population size, and research can shed some light on the biological objectives for each approach. Concern for inbreeding depression has, for example, led to the recommendation of an effective population number of about 50 (see for example Frankel and Soulé 1981), but if it is established that the species suffers severely from inbreeding, the requirement may be for a much higher number. Maintenance of genetic diversity ‘in the long run’ through a balance between genetic drift and polygenic mutation rates (see for example Franklin 1980; Lande and Barrowclough 1987) has led to recommendations of 500–5 000, but these numbers are highly dependent on the expected polygenic mutation rate. In principle, therefore, genetic studies such as selfing rates, number and effects of rare alleles, inbreeding depression, polygenic mutation rates or natural selective forces could aid the decision on target population sizes. However, it is difficult, expensive and time consuming to estimate such genetic parameters accurately, and they are therefore rarely available in most conservation programmes.

Furthermore, the required population sizes (50–5 000) are actually ‘effective population’ (Ne) numbers that cannot be directly used as guidelines. The effective number will only equal the actual number of trees under a set of so-called ideal conditions (Frankel and Soulé 1981); for instance, all trees are mature, all trees flower equally, all trees mate randomly with each other, and all trees produce the same amount of seed. This is highly unlikely, so the effective population number is typically smaller than the actual number of individuals in real populations, and may be as little as half the census number (Nc) (Lynch 1996). A key question is therefore the relationship between actual number of individuals (Nc) and the effective population number (Ne). This is particularly important when it is difficult and costly to include additional trees in the conservation population.

The relationship between Ne and Nc can only be established by studying factors such as variation in fruiting, the presence of family structure, assortative mating and overlapping generations. Of these factors, variation between trees in seed set is usually the easiest to assess, because this can be done by relatively simple observation or collections. Also, variation in seed set and reproductive success in the stand are probably among the most important reasons for reduced effective population size. This may be especially true for species where a complicated interaction with pollinators is disturbed by human influence. In such cases observations on seed or fruit setting may be very valuable, and scattered or missing fruit set would indicate that management has to be modified.

In situ *gene conservation area for teak (*Tectona grandis*) at Ban Cham Pui, Lampang, Thailand. (Erik Kjær/DFSC)*

In practice, the number of trees must be estimated from the estimated size of the protected area. This requires some data on approximate number of mature trees per hectare, which can differ largely between species, and populations within species. The Ban Cham Pui teak forest (see figure) carries more than 50 mature trees per hectare (DBH >30 cm), whereas other Thai teak conservation stands are found to contain less than 15 such trees per hectare (Graudal *et al.* 1999). In species-diverse forests, the densities may be very low. Hubbell and Foster (1990), for example, report a large number of tree species being present with only 1 tree per 50 hectares in an old-growth forest in Panama.

In fact, when it comes to ensuring the long-term survival of a given population, demographic and environmental factors may easily be as important as genetic processes (Shaffer 1981; Lande 1988). Environmental modifications that influence the abundance of pollinating vectors (see for example Bawa and Hadley 1990; Owens 1994), or changes in the microclimate necessary for successful natural regeneration (Graudal *et al.* 1995), are examples of such factors that are likely to be very important for maintaining populations of tree species over several generations. These factors are often more or less directly related to area, because suitable environments—and any of the required interactions with other species—often require conservation units of hundreds of hectares. For relatively densely distributed species, such a large area will probably contain many more trees than are required from a purely genetic point of view. Regular monitoring of the seed and fruit setting, and/or occurrence of natural regeneration, is thus important.

4.6 Information and research that support development of guidelines for the management and use of conservation populations

Human activities in conserved forests can have genetic implications and be in conflict with the objectives of conservation. Obviously the key question to be addressed by research is what kind of use can be accepted, or what kind of management will be required.

Logging and other use of forests can influence their conservation value, as discussed in Vol. 2. Alteration of species composition and microclimatic conditions associated with logging may reduce the reproductive capacity of such tree species by decreasing the population size of their pollinators (Owens 1994). Logging of specific low-density tree species can also increase the average distance between two trees of the same species, to an extent where the chance of cross-pollination is reduced. Reduced outcrossing can be quite serious for many species, leading to inbreeding depression or reduced fertility (Bawa 1994). Changes in outcrossing rates after logging can be studied by using genetic markers (Ghazoul and McLeish 2001) as well as estimating outcrossing rates over time (Ritland and Jain 1981). However, the best way to monitor the overall fertility success in the field is to make regular observations on seed or fruit setting and natural regeneration rates. It is quite common for tree species only to flower at irregular time intervals, and the results of such monitoring must therefore be evaluated over a certain time frame. Occurrence of natural regeneration is a general indicator of fertility, but this should also be evaluated keeping the very dynamic nature of most forests in mind.

A natural line of reasoning based on observations over a period of monitoring could, for example, be:

- Is natural regeneration absent?
- > If yes: is fruit set poor?
- > If yes: is flowering poor?

Poor flowering over a long period of time could be caused by a dramatic change in microclimate, because initiation of flowering is often triggered by climatic factors. Low seed production, in the presence of good flowering, may be caused by low density of pollinators (see for example Dreistadt *et al.* 1990, Ghazoul and McLeish 2001), or environmental factors such as water stress. When seed production is adequate, an absence of seedlings on the forest floor may be caused by grazing, fires or conditions unsuitable for germination and growth. Results from research that monitors regeneration could lead to interventions that might improve the conservation status of species in the conserved areas. Such monitoring cannot, of course, be done for all species; however, it is likely to be less expensive than genetic marker studies, so a fair number of species could be included. Species might be selected for study because of their high priority (see Section 3.3), and/or because they represent different ecological life strategies.

Selective logging of straight trees may cause directional genetic selection towards trees of low economic value and poor stem form. The possible effects of selective logging depend on the heritability of the trait being selected (see for example Falconer 1989), and on how the selection is performed. In natural populations with mixed species and ages, heritability is probably low for traits such as growth, but somewhat higher for stem form. The genetic response following moderate selection is, therefore, expected to be generally low, whereas more severe degradation of forests will cause more rapid and important genetic changes and reduced commercial value in future generations (Ledig 1992; Savolainen and Kärkäinen 1992).

The heritability for selected species and traits can be estimated in field trials, where the progeny from selected trees are grown and compared (see for example Lynch and Walsh 1998; Falconer 1989) (also see Vol. 3, Chap. 4). This is usually only applicable for species that are typically grown in plantations, and—as they require time and resources—such studies are possible only for high-priority species already subject to some form of breeding or pre-breeding. For most specific conservation programmes, information on the heritability of selected traits would be desirable, but not crucial.

Strong negative selection (the logging of high-value trees) should, of course, not take place in conservation areas. However, when conservation and use are combined in larger areas (see Box 4.3 for an example), these kinds of studies (i.e. provenance or heritability studies) can be quite important. Before starting field trials, it is important to remember that results may not be available for several years, or even longer.

Grazing and fire may disturb natural regeneration, introduce new selective forces and influence the competition between species. Severe fires may result in total destruction of the prevailing ecosystem and thereby initiate substantial migration involving pioneer species. Many forest ecosystems are adapted to occasional fires, but a higher than normal frequency can cause problems for regeneration of some species. For example, repeated fires have been identified as major obstacles to natural regeneration in natural *Pinus merkusii* stands in parts of Thailand (Theilade *et al.* 2000) and in natural *Baikiaea plurijuga* forests in Zambia (Theilade *et al.* 2001). Land use that includes burning and cattle grazing may influence the genetic resources much more severely than selective logging. Again, such processes are

Box 4.3 An example of combined use and conservation in gene resource management units in Malaysia

The Permanent Forest Estate (PFE) in peninsular Malaysia is classified into protection, production, amenity, research and education forests:

- **Protection forests** are areas which are not exploited for timber, but are maintained in a natural state to protect the hilly areas and watersheds, and to conserve genetic resources.
- **Production forests** are managed for timber production and are logged with cutting cycles of 30–55 years.
- **Amenity forests** are set aside for recreation, ecotourism and public awareness in forestry.
- **Research and education forests** are set aside for research, education and conservation.

Before 1979, almost all production forests were under the Malayan Uniform System (MUS); currently the system of management is either MUS or a selective management system (SMS). Under the MUS all trees over a specified diameter were felled, and under the SMS the diameter limit is set on the basis of stocking expectations in the future. However, both systems selectively remove the biggest trees and strong genetic erosion (or dysgenic selection) is expected to occur.

Gene resource areas (GRAs) have been proposed in many countries, for many conservation projects over the years. Management practices for GRAs can vary, but they tend to have one common objective: to maintain viable populations and genetic diversity of the original population. One such (GRAs) has been proposed within the Ulu Sedili Forest Reserve in Malaysia. This is made up of 30 compartments, 19 of which have been logged while 11 are not logged but scheduled for the future. Initially eight target species have been identified for conservation measures. Although individual species require individual management considerations, after the initial inventory was carried out in one of the compartments, it was decided that at least 50% of the trees over 30 cm DBH should be left. Two of the eight species had a complete restriction on cutting, and others had larger minimum DBH limits.

It was proposed that the GRA project will continue for 10 years (until approximately 2005), and monitored regularly (every 5 years) after logging. Broader applications of these principles and methods will hopefully benefit Malaysian forestry by ensuring socioeconomic returns from the forests, sustaining irreplaceable genetic diversity and maintaining environmental protection for years to come.

Source: summarized by A. Yanchuk from Tsai and Yuan (1995)

best monitored by observing development over time in the distribution of species and size classes, including the presence of regeneration. Regular monitoring is therefore valuable, to make it possible to intervene if the situation is seen to be in conflict with the conservation objectives.

Although it is often important to combine use and conservation of trees, the domestic use of trees may have many genetic implications. Seed used for propagation of trees grown on farms is often collected from a few nearby trees, and this can have quite strong genetic implications, especially for outcrossing species. Understanding the historic distribution of germplasm at the landscape level is therefore important in evaluating the potential genetic implications of collecting and subsequent domestication activities. Surveys of the present channels for procurement of seeds, including interviews with farmers, are one way to shed light on where germplasm has originated and how it is distributed. This understanding can be an important starting point when designing strategies for sustainable management of genetic resources of planted trees.

Important selective processes may also be involved in the propagation and cultivation phase. From a conservation point of view, it is also interesting to know to what extent different traits are genetically correlated; that is, whether selection for one character results in unintended change in another. Estimation of such correlations requires progeny trials, but this information is normally expected to be available only for species of high present use and value (see Vol. 3, Chap. 4).

Many species are not planted at present, although they may have a large potential for planting. Putting such species into use, as part of an integrated use and conservation plan, may require research on cultivation of the species. Such studies can focus on problems related to seed procurement, plant production, establishment, cultivation and/or use of the end product (Hansen and Kjær 1999). Initial screening of a larger number of trees may be an important way to identify species with potential for use (Butterfield 1995).

4.7 Conclusions—where to put the research effort?

Demographic surveys of target species are often an important part of a conservation programme. Such a survey should reflect ecological status and development (such as occurrence of trees of target species and successful regeneration), as well as human impact and potential threats.

Although it is important for decisions about forest genetic conservation to be based on a genetic understanding of the species of interest, it is important to note that this is not necessarily a prerequisite for action. In most cases, the conservation of forest genetic resources requires representative populations from ecologically representative or distinct areas, and an overview of the conservation status of different populations. Of course, genetic research *per se* is important to improve our general understanding of genetic processes, and thereby improve the general concepts and selection of specific populations and management activities for conservation. Forest genetic research is also highly useful in capacity-building and training of geneticists who can understand, promote and carry out the necessary field work. Careful consideration should be given to the role, specific conservation objective and likely impact of any genetic research studies that may be undertaken.

PEOPLE'S PARTICIPATION AND THE ROLE OF GOVERNMENTS

by Lotte Isager, Ida Theilade and Lex Thomson

5.1 Introduction

Millions of people, representing a great variety of cultures and land-use practices, live in or on the edges of forests. In tropical environments, many of these people are shifting cultivators who have for generations lived in and used the forest according to their particular fallow system.

Although they live in or near forested areas and are dependent to varying degrees on natural forest products, a large number of these people have experienced increasing difficulties in gaining access to local forests and their products. These difficulties may arise due to deforestation, logging, population pressure or increasing government regulations including declaration of state forests, national parks or wildlife reserves.

In many countries, plans to protect forest ecosystems in forest reserves and protected areas have failed to consider the needs and knowledge of local people (Anan Ganjanapan 1996; Wily 1997; Tuxill and Nabhan 1998; Kumar 2000). It is becoming increasingly accepted that the participation of local people is essential for effective conservation of protected forest areas. However, their participation and efforts in the conservation of specific target tree species are less well documented.

Participation in forest conservation is often associated with the concept of community forestry. Community forestry basically means that a forest is managed or co-managed by people who live close to it. Legal, political and cultural settings within which community forestry is practised vary considerably, and accordingly, the term can include a range of different experiences and practices. Community forestry is often associated with South and South-east Asia, but community-based forestry is also found elsewhere and is being developed in other regions (Wily 1997).

Indeed, it can be argued that community forestry has almost always existed. Before the advent of modern forestry regulations and centralized administration, local people managed most forested areas. Even so, traditional ownership and management in the past should not be equated with community forestry practised today. Within the confines of modern nation states, characterized by comparatively higher pressure on forests resulting from increased local and global demand and by easy forest and market access resulting from infrastructure development, community forestry must still largely participate at state, national and international levels.

Local participation is important in almost all forest conservation, but there are situations where it is absolutely necessary, for instance in areas characterized by high population pressure and conflicts of resource use; in areas under communal ownership; and in smaller protected areas because of the vulnerability to surrounding human activities (see Roche and Dourojeanni 1984). In these cases conservation in the absence of local participation will almost certainly fail. At the same time, it will be argued in this chapter that participation in itself provides no guarantee of success. This is because the outcome of participatory processes often depends on additional factors such as the institutional and legal backing provided by the state, or on the education and interests of local people and other stakeholders. As the case studies presented in this chapter show, governments and their agencies play significant roles in participatory processes by providing—or not providing—the 'enabling environment' for these processes to develop fully. Indeed, many studies suggest that the optimum formula for conservation is joint control and management by the government and local people (see for example Singh 1996; Hirsch *et al.* 1999).

Engaging in participatory processes, and creating an appropriate legal and administrative environment for them to proceed, are vital and complementary aspects of the conservation of forest genetic resources. In order to stress this, the present chapter deals both with the different perspectives of participatory processes and with key elements of enabling environments—that is, appropriate institutional and regulatory frameworks provided or affirmed by the state, secure land tenure, and various forms of capacity-building. The chapter is not meant to provide a thorough academic analysis of the complex political and cultural issues related to forest conservation and people's participation. Rather, the intention is to offer an overview of important aspects of the political and cultural context within which participatory processes inevitably take place. Accordingly, some practical suggestions as to how these processes can be improved are presented.

It should be noted that participatory methods such as participatory rural appraisal (PRA) techniques are not discussed in this chapter as there is already a comprehensive and readily available literature on this subject (for example Chambers 1992; Wilde and Vainio-Mattila 1995a,b,c; Davis-Case 1989, 1990).

This chapter directs attention to a number of concrete participatory conservation processes currently under way in different parts of the world. None of these case studies is ideal in the sense that conflicting interests, social conflicts, or technical difficulties are absent. Even so, the case studies presented here are far more positive than most examples found in the world today. It is, indeed, a deliberate choice not to repeat well-known cases of participatory processes gone awry but, instead, to focus on how, through a combination of cooperation and political struggle, people have managed to deal with inevitable problems and conflicts in a constructive and innovative way.

5.2 What is participation?

The concept of participation originally grew out of a radical criticism of the mainstream development projects of the 1960s and 1970s. Critics asked why development projects often did not lead to the expected results, and came to the conclusion that lack of people's participation was the problem. Too many projects, it was argued, were designed and implemented without debate and cooperation with people whose lives were to be changed by the projects.

Since then, unfortunately, the term 'participation' has been overused and it has become part of development jargon. It seems ever-present in project descriptions and plans, often because donor organizations, largely for political reasons, demand that projects use a 'participatory approach'. Unfortunately, project planners and implementers frequently talk of 'participation' while continuing their traditional style of management without any real involvement of others (Wily 1997). Nonetheless, real participation remains a goal worth striving for.

Developers and conservation planners often mean very different things by the term 'participation'. Adnan (1992) defined three basic meanings of the term that are often encountered:

- A process in which information about a planned project is made available to the public. This type of participation often involves only community leaders. These people are listened to, but the decision-making power rests with the outside planners and project implementers.
- Project-related activities, rather than mere information flow. This might involve labour

from the community, or a longer-term commitment by local groups to maintain services or facilities or even to plan for their future use. Again, the initiative has come from outside. People are involved, but not in control.

- A project that is the direct outcome of people's own initiatives. A well-known example of this form of participation is the Chipko movement which began in the Himalayas in the 1970s, when women mobilized themselves to protect the trees that were vital to their economy (Shiva 1988).

The outcome of participation depends also on factors such as the institutional and legal backing provided by the State. (Ole Hein/Nepenthes)

There are many intermediate forms between the three categories. Some people have therefore claimed that because it can have so many different meanings the term 'participation' has become meaningless, too often serving to disguise a continuation of top-down planning (Rahnema 1992). Others have argued that it is not reasonable to describe a process as participatory if local people are merely asked to supply information or labour to a project already designed and decided by planners (Gardner and Lewis 1996). In line with these arguments, we consider it real participation when people are involved in the planning, organization and decision-making of a project from the very beginning in order that the project fits their needs and capabilities.

5.3 Participation as a social process

People's participation is essential in development projects as well as in conservation of natural resources including forest genetic resources. If effective participation in conservation means involving people throughout the organization and decision-making processes, the question of how to create this kind of participation then arises. To begin with, it is helpful to think of participation as a process of communicating and working together with different people and groups in order to achieve a common goal. Participation is learning from each other's knowledge and mistakes; it is not something that can happen only once. It is a time-consuming process made up of different steps or phases, each of which presents new insights and challenges. Participation is sometimes difficult, but the rewards of truly participatory processes are often impressive, as more effective forest conservation is achieved (World Bank 1996; Wily 1997).

Conservation of forest resources requires that stakeholders trust one another and commit themselves to the task of sustainable forest use. In order to build up relations of trust, legal or administrative procedures may have to be changed or power redistributed. Often, mutual trust needs time to develop, especially if stakeholders have no previous experience of sharing decision-making powers and management responsibilities. Individual planners and other stakeholders can do much to strengthen relations of trust by listening carefully to ideas or complaints brought forward by others and by acting in a considerate and genuinely respectful manner towards all involved. Above all, it is worthwhile noting that it is the concrete actions of stakeholders in relation to each other, rather than their words or promises, which ultimately determine whether trust evolves or not.

It is important to consider how a conservation process in itself may or may not help

Box 5.1 Joint forest management in India

In India about half of the states have endorsed a strategy of joint forest management (JFM) in which forestry departments and communities jointly manage forests and share responsibilities and user rights. The idea of JFM originated in West Bengal when a forest officer involved forest fringe communities in the management of sal (*Shorea robusta*) forests that had been reduced to bush by overexploitation. The result of community involvement was a remarkable rejuvenation of the sal forests. Analyses of Landsat images showed that the closed forest cover increased from 11 to 20% in Midnapore District alone. In southern West Bengal, despite continuous population growth in the past two decades, involvement of people in managing their forests has resulted in many square kilometres of degraded scrub forest being upgraded to open forest category.

Encouraged by this success, the Indian Government expanded the programme during the 1990s. Today, nearly 4 000 km^2 of degraded forest is managed by more than 3 500 forest protection committees and includes 5.5% of the forest cover in India (Saxena 1999).

Under JFM the legal ownership of land remains with the government forest departments; village committees are co-managers of the forest and are entitled to shares in forest products. Forest protection committees control access to the forests and manage them. These local community institutions are proving more effective than state forest departments in protecting the forest. Regenerating forests now provide more medicinal, fibre, fodder, fuel and food products for rural people, whose livelihoods are thereby improved.

The JFM strategy has required a change of attitude from both forest departments and rural communities. Rural communities have had to organize themselves in new ways, overcome village and inter-village conflicts, and work together with forestry officials. Foresters have had to communicate with local people and share decision-making power. To enable this process of participation the Indian Government has provided legal and institutional backing, including land reforms, social forestry programmes, sharing of user rights with the people, and education of foresters to deal with participatory processes.

It has been argued that JFM in India is a concept describing divergent experiences ranging from real participation in decision-making to mere execution of government officials' orders (Kumar 2000). Often, forestry officials lay down the rules for forest protection committees, and the partnership between forest departments and village communities is generally unequal as most power rests with the former (Tewari 1996). Conflict between local groups over land and tenure rights is another challenge in JFM, just as unsolved questions about the legal status of customary rights in many cases make local forest management difficult in practice (Buckles and Rusnak 1999).

A major lesson learnt from the JFM experience in India is that involving local communities in management of forests has led to more effective forest protection. Another major lesson is that sustainable conservation depends on the cooperative attitudes of local people and forestry officials and, significantly, on the legal and institutional backing of the state.

Based on Singh (1996)

Box 5.2 Conservation of FGR in Thailand

The Khong Chiam *in situ* gene conservation forest (GCF), located in Ubon Ratchathani Province in north-east Thailand, is one of a handful of forested areas in South-East Asia which has been set aside specifically for conservation of forest genetic resources. In 1983, an area of about 700 ha was reserved with the objective of protecting the genetic resources of local tree species, especially the lowland form of *Pinus merkusii*. This form of *P. merkusii* has a faster early growth than highland sources. It has good potential for use in replanting programmes and is considered a high-priority genetic resource. The Khong Chiam population of *P. merkusii* is one of only six known lowland populations in Thailand, all of which are highly threatened. Other important tree species conserved in the Khong Chiam include *Anisoptera costata*, *Dalbergia cochinchinensis*, *Dipterocarpus costatus*, *Ivingia malayana*, *Peltophorum dasyrachis, Pterocarpus macrocarpus* and *Schima wallichi*.

Initially, major conservation activities consisted of mapping and demarcating the area; establishing access/inspection roads and firebreaks; relocating illegal settlements; and prohibiting agricultural activities, resin tapping, charcoal burning and firewood gathering. Early on, the GCF functioned successfully thanks to local Thai Royal Forest Department (RFD) staff who cultivated good relationships with local people. Awareness of local people about conservation issues and the purpose of the GCF was raised through an informal public education campaign.

In the late 1980s, the surrounding villages experienced a considerable increase in population as immigrants arrived from neighbouring provinces. This led to increasing pressure on land and resources. Through the 1990s, the capacity and will of local forestry staff to enforce GCF regulations declined. By 1997, several illegal dwellings had appeared within the GCF and agricultural activities had begun. Almost all mature *P. merkusii* trees were being used for fire-stick production. Pine regeneration was sparse as a result of limited production of viable seed and an unfavourable regeneration environment. Illegal logging and charcoal production were threatening other important tree species within the GCF. By 1998, it was evident that the conservation approach based on protective and prohibitive regulations by forestry staff, limited by insufficient budgets and support from other agencies, was unsuccessful (Granhof 1998). An inspection in 1999 revealed that nearly all pine trees were severely damaged by fire-stick cutting and at high risk of dying.

One lesson learned in Khong Chiam is that conservation of forest genetic resources was not possible without the active support and participation of surrounding communities. Another lesson has been that sustainable conservation depends on continuing good relations between forestry staff and local people. All staff members should be educated about how to communicate and cooperate with local people, so that good relations do not depend solely on the qualifications of specific individuals. A third lesson is that cooperation between different government agencies is necessary for securing sustainable conservation.

In response to these experiences, the RFD and the Forest Genetic Resources Conservation and Management Programme (FORGENMAP) has now included the Khong Chiam GCF in a new network of pilot *in situ* conservation areas known as 'Partnerships in Conservation of Forest Genetic Resources'. A participatory approach will be used, based on the community forestry approaches developed by the Regional

continued

Community Forestry Training Centre (RECOFT) and successfully applied elsewhere by provincial RFD staff. However, if *P. merkusii* is to be conserved in the GCF, this approach will need to be supplemented by more urgent conservation measures including (1) enforcement of prohibition on fire-stick production; (2) control of grazing buffaloes that eat regenerating pine; (3) promotion of natural regeneration by creating suitable seed bed conditions adjacent to seeding *P. merkusii* trees; (4) collection of seed or taking of grafts of surviving *P. merkusii* for establishment of a small gene conservation stand in a secure location in Ubon Ratchathani.

Sources: Royal Forest Department, Thailand; and Jens Granhof/FORGENMAP (1998)

catalyse relations of trust and commitment among stakeholders. An ambitious timetable for a given conservation activity may, for example, make it difficult to ensure the trust and commitment of all stakeholders. Often, such projects are envisaged to last just a few years before the 'outsiders' leave an area again. If project personnel depart before the positive effects of conservation activities become visible for local stakeholders, then the latter are less likely to remain committed to the conservation process.

Villagers, the local NGO Nature Care and Royal Forest Department, Thailand, discuss the management and conservation of natural forests around the village.
(Ida Theilade/DFSC)

Donors' preferences for large-scale rather than small-scale projects can also inadvertently lead to barriers to trust and commitment. This is especially true if project managers (be they local people or 'outsiders') want other stakeholders to commit themselves on a level beyond their capacities and aspirations. Such an approach, sometimes proposed with the best of intentions for people's participation, can make other stakeholders insecure and end up leading to no commitment or involvement at all. In order to avoid such situations, conservation activities need to be organized so that stakeholders—particularly those with no previous experience in participation—can commit themselves gradually, task by task, and progressively build up relations of trust. All key stakeholders should, therefore, be involved in conservation activities from the very beginning of the planning process, including collection of baseline data, to the actual implementation of forest co-management.

5.4 The participatory approach in conservation of forest genetic resources

As mentioned previously, no two participatory processes will ever be exactly identical because people, forests and other circumstances vary from place to place and from time to time. Even so, most participatory processes will involve a number of different phases or steps for conservation of forest genetic resources.

Step 1: identification of the species and areas to be protected

It is debatable whether this activity can—or should—always be participatory in the real sense of the word, since conservation objectives tend to be defined initially by government officials or scientists. There are, however, cases such as the Chipko movement and the South Pacific Biodiversity Conservation Programme (see Vol. 2, Box 4.7), where people define their own conservation goals, which are then brought to the attention of the government.

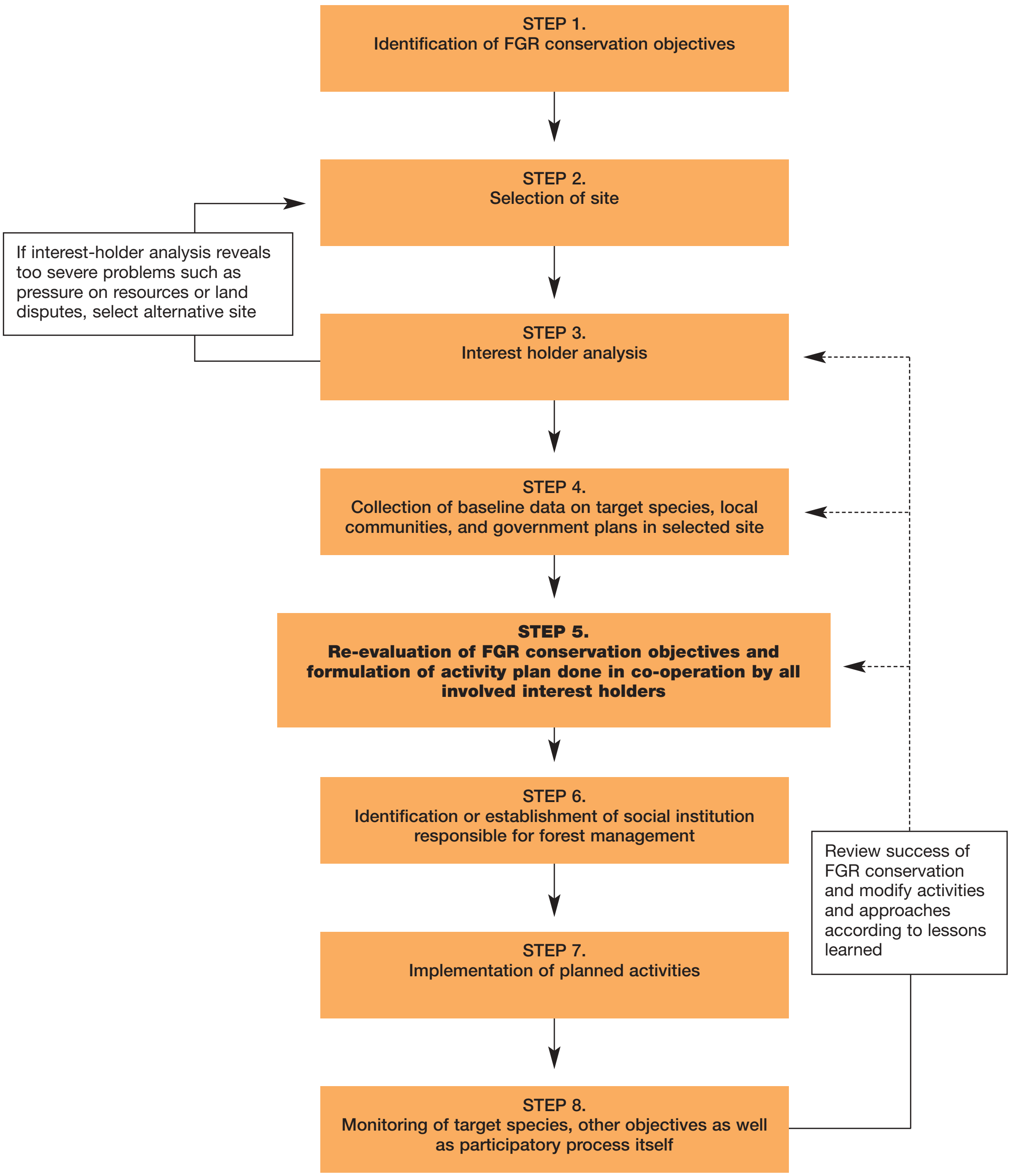


Fig. 5.3. *A model for a participatory process in conservation of forest genetic resources (DFSC).*

Whether the initial formulation of conservation objectives comes from government conservation planners or from local groups, in a truly participatory process, it is vital that these objectives remain open for discussion and reformulation once other stakeholders have become involved in the planning process. In Fig. 5.3 this is illustrated in step 5, which states that all stakeholders should participate in the re-evaluation of conservation goals.

Step 2: identification of suitable sites
Among suitable areas one or more will be selected; again, it is likely that this phase might not always require full participation. If sites are initially selected by, for example, government planners and scientists, it is crucial that other stakeholders are able to challenge or change this decision later on in the process. At a minimum, local stakeholders should be able to provide local information on individual stand characteristics that might be considered important in the scientific assessment period.

Step 3: stakeholder analysis
In this phase several questions need to be clarified (see Grimble *et al.* 1995; Danida 1996):

- Who will be affected by conservation activities?
- What are their interests?
- Who has a right to participate?
- How do different stakeholders affect the conservation area?

During this phase it is important to consider that people's interests in a particular species or forest area cover more than simple economics. Trees and forests may have religious, spiritual, recreational or aesthetic value for people, and these can be as important as economic interests. Depending on how they feel about conservation activities, different stakeholders may want to participate in different ways. If a group of people or a local community is defined as one stakeholder, it should be remembered that all members of this group, or a multitude of groups, may not have the same interest in, knowledge of, access to, and rights over the forest and its resources. This can also be true with government, or non-governmental agencies, as in many countries different government agencies and departments can be involved in land and forest management. See Table 5.1 for an example of a stakeholder analysis.

Step 4: collection of baseline data
At least three different types of data are necessary:

- government policies and plans regarding the sites proposed for conservation of forest genetic resources
- data about and from local communities
- data on the forest and its resources.

Ideally, a team of professionals and stakeholders, including the local communities, should work together to collect the baseline data.

As mentioned above, different government agencies may hold authority in a particular area, and sometimes their plans for that area are not compatible. It is crucial for planners to know whether existing government plans may inadvertently conflict with the objective of conservation. If this is the case, alternative conservation sites must be considered unless the government department is prepared to change its plans.

It is likewise vital to obtain information about local communities. Much of this can be collected together by the people themselves and supplemented from official information sources. How do people organize land and forest use? What is the local land-use history? Do people hold user rights over the forest? Will they benefit from the conservation of forest genetic resources? What are the trends in population pressure? What are people's needs in terms of subsistence? Clearly, conservation measures in which benefits outweigh costs for local people stand a better chance of success. Using people's needs and forest management practices as the starting point will make conservation more likely to succeed in the long run.

Baseline data on a forest and its resources are obviously necessary for conservation planning. Forest surveys and inventories should be undertaken. Historical trends in resources should be established. Have particular tree species disappeared or become rarer? Is regeneration sufficient? In some cases such information can be obtained by involving local people in land-use and resource mapping (see Box 5.3).

Step 5: re-evaluation of objectives

Having identified all stakeholders and collected baseline data needed for further planning, stakeholders need to meet and re-evaluate the objectives of conservation activities. During this phase, specific conservation activities, timetables and resources required need to be defined as well. There may be cases where conservation objectives have been identified and sites have been selected by government officials or other conservation planners alone. In such cases it is crucial that hitherto non-involved stakeholders become real participants at this stage of the conservation process. Some stakeholders might identify goals and activities considered by them to be vital for sustainable forest conservation—for example, acquisition of tenure or forest user rights, formal government recognition of customary forest rules, or training of stakeholders. Such social and political goals may be as important to these stakeholders as specifically forest technical objectives are to others.

Step 6: identifying the institution to be responsible for conservation activities

In some cases appropriate institutions may already exist and be in a position to take up responsibilities for implementing and monitoring conservation activities. In other cases a forest management committee may need to be established. It will be important to consider, for example, how different stakeholders are to participate. Is the committee to be locally constituted or should outside agencies be included? How should communication be organized? How should activities be monitored, and by whom?

Steps 7 and 8: implementation and monitoring

During these phases a conservation project will find its own form as various activities progress. Implementation of activities or monitoring of target species and, not forgetting the social or political aspects of the conservation process itself, will automatically lead back to previous steps in the participatory process. As illustrated by the dotted lines in Fig. 5.1, it might be necessary to make a new stakeholder analysis because additional stakeholders have appeared or because the involved parties acquire new interests or, indeed, lose particular interests in a species or geographical area. Likewise, at any time during a participatory process, stakeholders may realize that available baseline data need to be revised or supplemented by additional forms of information, for example because the very process itself has led to social or economic changes for the involved parties. Projects need to be designed with a high degree of flexibility to accommodate such changes. Implementation and monitoring should also be participatory.

Table 5.1 Stakeholder analysis, Khong Chiam *in situ* conservation area, Thailand

Stakeholders	Interests	Activities	Influence on forest genetic resources
Local villagers (long-term residents, recent immigrants, and forest users)			
	Food	Harvest of subsistence food sources (including nuts, fruits, tubers and fungi)	Minimal impact
	Timber	Harvest of timber for local buildings and other purposes	Threat to preferred species
	New land for growing crops	Forest clearing	Threat to ecosystem
Medicinal plant harvesters	Medicinal plants	Harvest of leaves and bark for traditional medicines	Very limited impact
Resin tappers	Resin	Tapping of Dipterocarps for resin production	Limited impact
Fire-stick collectors	Fire-sticks	Harvest of *P. merkusii* sticks for sale	Major impact—threatening *P. merkusii*
Charcoal producers	Charcoal	Cutting of timber for making charcoal for sale	Threat to preferred species
NGO: Nature Care			
	Forest conservation Well-being of local villagers Equal benefit sharing	Public education	Maintain forest genetic resources through use
Government agencies. In Thailand, 19 different government departments and agencies are involved in land management, including:			
Thai Royal Forest Department	Forest management and conservation	Enforcement of forestry legislation and regulations	Conservation of forest genetic resources *in situ* and *ex situ*
	Research Pilot area in partnership in conservation	Research Workshops with local people	Domestication and improvement programmes for priority tree species
Provincial Government	Development	Local infrastructure and provision of Govt. services	Various impacts, often negative, depending on activities
Donor project: FORGENMAP/DANCED			
	Conservation of forest genetic resources and ecosystems Pilot area in partnership in conservation	Training of forest department staff Seed supply Workshops with local people	Conservation and improved utilization of forest genetic resources

5.4.1 Assumptions about local communities and people

In conservation projects, a village or local community may sometimes be identified rather broadly as a single stakeholder. However, it is important to question this as well as other assumptions about local communities. Here are some examples of frequently held incorrect assumptions:

- **Local communities are homogeneous entities.** Most local communities are, in fact, characterized more by social divisions than by equality in terms of land holding, power and knowledge. Women and men may have different interests in a forest. ‘Landless’ people may desire access to the forest and its resources for purposes other than those of the landholders. If only community leaders (who are typically male) are involved in a participatory process, there is a risk that the interests of other groups within the community are neglected. Failure to consider the views of all community members is a common source of conflict.

- **Local communities live according to stable traditional values.** The idea that rural communities do not change or acquire new knowledge, habits and interests is wrong. Social and cultural traditions change as people get new options, ideas, and technology.
- **Local communities depend on forest products for their livelihood and, therefore, have an interest in protecting the forest.** It is true that many people living in or on the edges of tropical forests are highly dependent on forest resources. However, in many countries infrastructure development and access to urban labour markets have made rural people much less dependent on forest products than they were in the past. In other words, it cannot be automatically assumed that rural communities feel that they need to conserve the forest.
- **Local people like the forest and therefore want to protect it.** In fact, cultural perceptions of the forest vary from group to group and country to country. Indeed, social groups often have different ways of thinking about and acting towards the forest, which to outside observers might seem unintelligible or paradoxical. For example, while people may 'like' and treasure the forest in the sense that it provides them with fuel wood, food, medicine, and timber, the forest might at the same time be associated with negative meanings. In South-east Asia, for example, the forest has traditionally been perceived as the sphere of uncivilized and immoral beings including spirits, wild animals and ethnic minority groups. As such, the forest is linked to notions of backwardness and danger and carries a negative meaning for many people in these countries (Davis 1984; Stott 1991; Isager 2001). They may be keen to clear it and expand agricultural production, which in their view is more civilized and desirable.

Resin tapping generates income for local people at Khong Chiam gene conservation area, Thailand. (Ida Theilade/DFSC)

- **Local people destroy the forest because they do not care about it.** This assumption is possibly as common as the previous one. Both ideas rest on the underlying incorrect notion that people's perceptions and feelings about forests are straightforward and unambiguous and make them act in well-defined, standardized ways. In reality, people's knowledge (of the forest, for example) and the relationship between their knowledge and concrete actions are highly complex matters, and oversimplification should be avoided (see Barth 1993; Bourdieu 1990).
- **Local people have in-depth knowledge of their environment.** This assumption is as common as the opposite assumption that local people's knowledge about forests and biodiversity is irrelevant for conservation planners. In fact, forest-dwelling people have considerable knowledge of forest resources and ecology, and government planners or 'external advisors' too often underestimate this knowledge. At the same time, however, it should not be assumed that all people, by virtue of being labelled local or indigenous, have an in-depth knowledge of their natural environment. Different members of a local community know different things in different ways, and in any case people's knowledge is only one consideration determining how they act towards the forest.
- **Local people practise superior forms of landscape management.** Some groups

have developed remarkably fine-tuned landscape management systems, and recent studies of indigenous forest-management systems have shown that they often retain 50–80% of the biodiversity found in neighbouring natural forest ecosystems (Lawrence, Peart and Leighton 1998, cited in Poffenberger 2000). Nevertheless, it should be noted that traditional management systems have often been sustainable in the past because of low population pressure, geographical isolation, and lack of modern technology and machinery (such as chainsaws or logging trucks) rather than for ecological considerations (see Ellen 1986; Milton 1996). In other words, local or indigenous people's knowledge should not be idealized and it should not be assumed that it is their knowledge or culture alone that has made their management systems sustainable in the past. Rather, it should be discussed with local people which aspects of their traditional management systems can be most effectively incorporated into conservation planning.

5.4.2 Conflicts and how to solve them

Diverging interests and disputes among stakeholders sometimes grow into major conflicts. As observed by Ayling and Kelly (1997), there are no more 'resource frontiers' in the world and virtually every change of land use or expansion of resource use tends to involve conflict—be it between nations, regions, districts, or individuals. Within villages, divisions along family, gender or clan lines or long-standing personal enmities between individuals can be fuelled by land-use conflicts. Between villages there might be competition over resources. By promoting the interests of one village, or one group of stakeholders, conservation activities risk causing resentment among others. For example, external agents such as private companies or NGOs holding interests in an area will often not appreciate the local population mobilizing for purposes that go against their interests and ideas.

Conflicts are a natural part of social dynamics. Whether they are perceived as negative or positive depends on social position or political standpoint. Having said that, it is obvious that conflicts can cause problems for conservation activities if they are not resolved in a constructive way. If conservation activities affect specific groups negatively, this is likely to cause conflict. The risk of conflict will, therefore, be minimized if all stakeholders are involved throughout conservation planning and decision-making. However, even the most careful planning will not prevent conflicts from arising. Sometimes conflict may already be present. In this case the conservation managers have to decide whether it is too serious to resolve and whether the site should be abandoned for another.

We should distinguish between conflicts that need government intervention in order to be solved, and conflicts that can be dealt with by stakeholders themselves. The former category of conflicts is exemplified in Box 5.2 about forest genetic resource conservation in Thailand, where immigration from neighbouring provinces and forest encroachment led to conflicts with resident communities.

In some situations stakeholders can deal with conflicts without government intervention, according to local traditions of conflict management. Otherwise, the following guidelines for conflict management are helpful. They have been formulated specifically for conservation planners by the Foundation of the Peoples of the South Pacific International (Tapisuwe *et al.* 1998), an organization working with participation in conservation in Vanuatu (see also FAO 1994; Buckles 1999):

- All complaints should be taken seriously by planners. Listen to the concerns of both sides, and to fully understand the concerns, repeat them in your own words after listening. Think about the best time and place to discuss complaints. Remember that in many societies women are not expected to speak up in public hearings and other groups, such as poor or non-land owning individuals, may well, for their own reasons, remain silent during hearings.

- Planners should not try to solve the conflicts on their own. Discuss the matter with all stakeholders. Discuss why the complaint is being made. What are the underlying issues? What is needed to solve the conflict?
- If there are many problems or underlying issues that need to be dealt with, it is a good idea to prioritize them in terms of (a) magnitude (the amount of people, land, trees affected by a problem), and (b) importance (the impact a problem may have on different stakeholders).
- Encourage all stakeholders to look for positive solutions to any conflict they meet. Think about how to compensate those who are affected by a problem.
- Discuss and modify the options until everyone can accept the solution.

It should be noted that these guidelines depend on the voluntary participation of all relevant stakeholders. Cultural conditions, including people's willingness to publicly acknowledge a conflict, will make the guidelines more or less useful in different parts of the world. If the conflict-mediating process suggests that only certain stakeholders are brought together, while the real causes of conflict remain beyond the mediator's control, the process might in fact be counterproductive because people are likely to experience it as futile.

Local Dayak communities and WWF Indonesia work together to make forest management plans for Kayan Mentarang National Park. (Lene Topp/WWF Denmark)

5.5 How governments create an enabling environment

One of the lessons learned from joint forest management in India (see Box 5.1) and conservation of forest genetic resources in Thailand (see Box 5.2) was that higher levels of local participation could lead to more effective forest protection.

However, without government support, in the forms of law enforcement and cooperation between different government agencies, such improvements in local forest management are unlikely to be sustained (Tyler 1999).

Therefore, attention must be paid to the crucial role of government action for the outcome of participatory conservation processes.

A government can help provide an enabling environment for participatory forest conservation particularly through

- decentralization of political, fiscal and administrative power
- provision of land-tenure security and user rights for involved stakeholders
- education and other forms of capacity-building.

These three aspects are discussed below.

5.5.1 Decentralization

The conclusion from reviews of conservation experience in most countries is that centralized, top-down management is seldom effective, except where large budgets are available for enforcement and the society concerned is willing or forced to accept an undemocratic conservation process (World Bank 1996). It has therefore been suggested that the impact of public conservation efforts can be improved by enhancing the role of local governments and communities in decision-making. Such decentralization can be accomplished through the transfer of political, fiscal, administrative and legislative power from central governments to local institutions.

One form of decentralization or transfer of power occurs when specific groups of stakeholders rather than government officials have the right to collect revenue and decide how it will be spent. This autonomy is the key to the strength of the JFM areas in India, where local communities can retain all or part of the revenue from forest products. In Nepal, the government has granted rights of utilization and management responsibility to numerous local forest user groups. This decentralization of power has shown promising results in terms both of forest protection and of local people's willingness to participate in communal forest management and develop their management capacities (Tumbahanphe 1998).

The experience in countries where new rights and responsibilities relating to conservation have been given to local government units and NGOs suggests that both opportunities and potential problems exist (World Bank 1996). Poorly planned and implemented decentralization can give powers to local societies that lack the skills and accountability to use powers 'properly'. It should be kept in mind that the right to define what is 'proper' or 'improper' use of resources is in itself one of the most important forms of power in a particular social setting (Bourdieu 1991). Decentralization might also inadvertently lead to a situation where the costs of biodiversity conservation are borne locally whereas its benefits may accrue to regional, national and global levels of society.

In most cases local groups will need support from ecologists or foresters if they are to develop management plans and monitor conservation areas or populations. One such example of a decentralization process is the Kayan Mentarang National Park in Indonesia (Box 5.3).

Box 5.3 Indigenous people's mapping and conservation of biodiversity

Local Dayak communities and WWF Indonesia have worked together for some years to make forest management plans for Kayan Mentarang National Park in Kalimantan, Indonesia. The aim of this work was to produce a plan for community-based management of the national park. The plan has been recommended to the Indonesian Government with the hope it will be endorsed and implemented in the near future.

In 1992, the Dayak people of Kayan Mentarang began mapping their communities on an experimental basis, aided by WWF Indonesia. This was a continuous learning process for all involved. Accordingly, planning sometimes needed to be adjusted and objectives reconsidered. Then, in 1996, the Indonesian Government agreed to change the status of the Kayan Mentarang area from a Strict Nature Reserve to a National Park. The status of the Dayaks thereby changed from illegal settlers to communities that could legally be

continued

involved in the management of the area, by their own initiative and with support from WWF.

Encouraged by the government decision and the support of WWF Indonesia as well as the Indonesian Agency for Nature Conservation, in 1997–1998 the Dayaks conducted an extensive mapping of their communities and natural resources. They drew detailed maps of the flora and fauna in their area, showing where they collect plants or make use of trees, which areas they have cultivated over the years and where their traditional hunting grounds are. Other maps showed Dayak community boundaries.

Using participatory rural appraisal (PRA) techniques, WWF personnel helped the Dayak communities document information about their land-use systems, historical trends in resources, traditional forest regulations, and knowledge about forest resources. All this information was used in the development of a management plan for the national park.

Kayan Mentarang provides a good example of participation as an ongoing process where each party had to be flexible and accept new ideas. The government accepted changes to create an enabling environment. Thus the boundaries of the national park are to be redefined to accommodate the villages and their rice fields outside the park, and it is hoped that the Dayak traditional rules of forest management will become officially recognized. During the whole process WWF Indonesia Kayan Mentarang Project has been a main player and important facilitator.

The future management plan for Kayan Mentarang needs to secure the rights of the local communities to use forest resources and, at the same time, protect the biological diversity and genetic resources of the National Park. In the coming phases of conservation activities, there are plans to link the results of community mapping with the activities of the conservation biology programme of the Kayan Mentarang project. Thereby, the information on forest resources can be cross-checked from a biological point of view and the claims that traditional, community-based management practices are sustainable can be given scientific support. This approach may also raise the local people's awareness of the significance of integrating conservation and sustainable development more effectively. Another major task ahead for local people and the WWF personnel is to design community-based monitoring systems that include the use of community land-use maps and resource maps as well as other PRA techniques.

Sources: Worm and Morris (1997); Eghenter (2000); WWF (2000)

5.5.2 Security of land tenure and user rights

Lack of secure land tenure or forest user rights is a major reason why local people do not commit themselves to participatory forest conservation. As is to be expected, people without such rights experience a lack of a predictable future and a diminished willingness to invest labour and care in the forest. Once local people gain land or user rights, however, they often take an active interest in forest conservation. For the Dayak communities in Kayan Mentarang (see Box 5.3), the government's decision to change their status from illegal settlers to legal participants in forest management was a turning point. This provided the spark for increased community and resource mapping and conservation efforts. In Africa, according to a comprehensive literature survey by Shepherd (1992), effective *in situ* conservation is almost solely on lands under legally acknowledged ownership. In Melanesia, undisputed ownership to forest resources is seen as a prerequisite for replacing exploitative logging practices (Kuata *et al.* 1996).

In many countries, local groups have their own customary forest rules and regulations. By formally recognizing such rules, governments can greatly motivate local people to participate in conservation efforts. Official recognition of customary law can, however, be a complex issue. The legislation of some nations, for example, might not permit formalization of communal land ownership and customary laws of indigenous people. Considering the economic value of forests and the often fierce competition over access to forest resources, the question of granting tenure or forest user rights to local people is a highly controversial matter in many countries. This is partly because user rights in themselves provide no guarantee that 'new' private or communal land owners will manage forest resources in ways that are more sustainable and socially accountable than the previous government practices.

There are some discouraging cases from states in north-east India, where most forests are legally owned by tribal people. These states have experienced the highest deforestation rates in India over the past few years. Analysis has led to the conclusion that joint control and management by the government and local people is possibly the optimum formula for conservation (Singh 1996). This conclusion is similar to that of Hirsch *et al.* (1999), whose study from Nam Ngum in Laos demonstrates that a community alone cannot implement or enforce sustainable natural resource management without the legitimate sanction of the government. Clearly, each country will need to develop its own appropriate response to these sensitive issues. The experience from Tanzania (see Box 5.4) might serve as a positive example. According to the drafted Forest Act 2000, no forest in Tanzania is considered too large, too small, too valuable or too degraded to come under community-based management and, in certain cases, ownership. This approach differs from that of most other countries, where local people are only allowed to manage degraded forests but not the more precious national parks and forest reserves.

Forest resource map drawn by Dayak villagers, used to develop the management plan for Kayan Mentarang national Park.
(Lene Topp/WWF Denmark)

Box 5.4 The importance of land-tenure security in Tanzania

Duru-Haitemba and Mgori forest are two Miombo woodlands in the Arusha region, Tanzania. Five years ago both woodlands, under government control, were in a state of acute decline, with loss of area and species. In the case of Duru-Haitemba this resulted from boundary encroachment and in-forest settlement, excessive wood extraction and livestock grazing, mainly by local communities. In the case of Mgori the forest was affected by uncontrolled clearing for shifting cultivation, excessive hunting and timber extraction, mainly by outsiders.

Today the boundaries are intact, incursion limited, flora and fauna recovering, and both forests protected by a total of more than 200 young village forest guards—at no cost to the government. These developments have occurred under the Regional Forestry Programme and the Land Management Programme. Under these programmes the Duru-Haitemba, an area of nearly 9 000 ha, is now under the full ownership and active management of eight communities, and Mgori, a larger woodland of 40 000 ha, is currently owned and managed by villagers as five village forest reserves with the district council as technical adviser. The communities may begin timber harvesting within the next few years. This will create an income not only for the villagers but also for the district council in the form of a sales tax levied.

Neither Duru-Haitemba nor Mgori forest was at any time a state-owned and gazetted forest reserve. By the 1980s, they were intended as forest reserves and to this end had been fully surveyed and demarcated, and all but the publication of reservation was complete. It was clear, however, that local people did not support the withdrawal of what they regarded as 'their' forest into the hands of the state. Indeed, since the posting of forest guards to the area some years previously as part of the process, local people had more or less adopted a deliberate policy of 'getting what they could' out of the forest before their anticipated exclusion from the area. This led to both local concern and the ultimate decision to find a more acceptable system of management.

With informal support from the local authorities and the Swedish International Development Agency, the local forestry officer began to explore whether local villages could conserve and manage the forests themselves. At that time villagers had never encountered the possibility that they might be allowed by government to actually manage the forest themselves. The government itself had not envisaged the level of 'participation' put forward, but although dubious, they agreed to suspend the imposition of reservation status pending demonstration by the villagers to halt the degradation of the forest. Now, advisors and interested village leaders began a process to draw up simple but effective management plans including 'rules' for using the forest. Interestingly, before knowing that they might control the forest themselves, villagers cited virtually all uses from timber to grazing as 'indispensable'. Once it was known that the forest was 'ours', the same leaders and ordinary villagers argued for discontinuation of any use that they considered damaging. Charcoal burning, tree felling and even grazing in some parts were immediately banned, and other uses were to be controlled.

Once villagers began actively managing their forests, it became clear that they needed not just the administrative support from the local district office but legal backing as well. Accordingly, each village was assisted to rephrase their management plans and rules as village by-laws. In 1995, the district council formally approved these plans under the District Authorities Act. Since then, each village has by law been the legal authority and

continued

manager of that part of the Duru-Haitemba forest that is adjacent to its own settlement and specified as falling under its jurisdiction. In the words of a villager "It never occurred to us that the government might give us back our forest. But when it was suggested, we couldn't get the idea out of our minds and since then we have not looked back."

The situation in Mgori forest is slightly different. Five adjacent communities now successfully own and manage it, but first the areas had to be surveyed as legal entities for villagers to be registered as owners. In Mgori there is also need for a more active collaboration between villagers and local government, because the respective village woodlands are extremely large; two of the villages manage thicket and woodlands of more than 100 km^2. Mgori is therefore still vulnerable to a range of incursions by outsiders. This includes illegal commercial timber extraction, wildlife hunting, and the appeal the vast and remote area holds for migrating shifting cultivators. Also, Mgori has market potential for timber extraction and could generate revenue from game viewing and some hunting. Local government was ready to concede ownership of the resource but at the same time wanted to secure agreements whereby revenue from the forest in the future is shared with the wider district community through taxation.

These Tanzanian cases serve as examples that the greatest incentive for local people to look after the forest is the sense that the forest belongs to them, either as recognized managers, or better still, as recognized owners.

Sources: Wily (1997); Wily *et al.* (2000)

5.5.3 Capacity-building in support of a participatory approach

Throughout this chapter the key message has been that conservation of forest genetic resources is likely to be impossible without the participation of local people although, clearly, participation is not always required for sustainable forest use. Apart from appropriate institutional and regulatory frameworks provided by the state, and secure land tenure and resource utilization rights for stakeholders, education and other forms of capacity-building for stakeholders can be crucial if participatory processes for forest genetic resource conservation are to succeed.

The case studies presented in this chapter all show that participatory forest conservation poses considerable challenges to forestry officials, policy-makers, NGOs and scientists as well as local communities. In India, for example, the JFM strategy has confronted rural communities with the need to overcome village and inter-village conflicts and work together with forestry officials (see Box 5.1). Officials have been challenged to delegate part of their decision-making power to local people and adjust themselves to a new and more equal management partnership with these people. In north-east Thailand, rural groups have had to alter their agricultural practices and organize themselves in new ways to prevent forest-damaging activities such as charcoal burning and forest fires (see Box 5.2). They have also engaged in mapping and demarcation of their communities as a means of improving forest management. Meanwhile, Thai forestry officials need to adapt themselves to new political and administrative conditions and put more emphasis on working with people, rather than on mere technical aspects of forestry. Furthermore, they must learn to coordinate their own planning and administration with that of other government agencies.

Although they live in widely different parts of the world, Dayak communities in Kayan Mentarang in Indonesia (see Box 5.3) and people from Mgori and Duru-Haitemba in Tanzania (see Box 5.4) share the same experience of learning to make forest-management plans in collaboration with NGO workers or other external advisors. Policy-makers in both countries share the experience of being forced to modify land-use and land-right legislation, thereby helping to create the ‘enabling environment’ so necessary for participatory forest management to succeed.

In other words, each case in its own way demonstrates that participation entails changing social relationships, redistribution of power and new responsibilities for all parties involved. Often, these changes bring about a need for new skills, new ways of thinking and new ways of organizing. As the case studies show, different stakeholders meet different kinds of challenges during the participatory process. Some common challenges that typically face communities and government agencies are discussed below.

Communities

Communities often need to strengthen their organizational capacity in order to reclaim responsibilities in management and conservation of forest genetic resources. This may include development of competence such as practical skills in keeping records and minutes of meetings, or obtaining training in certain technical aspects of forestry and conservation. For some communities, training in mapping their own land areas and demarcating their forest boundaries can be of vital importance, not least as a starting point for future monitoring of resources (see Box 5.3). Communities that gain user rights over forest resources and start income-generating activities will furthermore have to acquire skills for financial accountability and sharing proceeds.

For many communities training in conflict management and resolution (see Section 5.4.2), to supplement traditional conflict resolution practices, might also be helpful. This is not only because participatory forest conservation management typically involves a number of communities that may not be used to cooperating, but also to develop ways of ensuring that the natural resources under their management are not taken over by more powerful and better-organized outside interest groups. Communities must therefore be strengthened in their ability to scrutinize the intentions of outside investors and developers, including NGOs, and turn away outside interests if these are not beneficial to the community.

Although many communities have experienced challenges such as those mentioned above, the needs of communities in regard to forest conservation cannot be generalized. Community needs may range from basic education in reading, writing and arithmetic to training in mapping, conservation planning, or use of geographical information systems (GIS). Likewise, it is not possible to give a universal definition of how various capacity-building activities are best organized among stakeholders. In some countries, the main responsibility for this rests with the government. In other countries, NGOs and universities play important roles in mobilization and training of local communities (see Box 5.5), partly because government agencies tend to lack the funding and experience or willingness to train local communities in administrative matters. Where government officials resist the prospect of sharing forest management power with local communities, this resistance is often also expressed in an unwillingness to share knowledge and information. In such cases, the assistance of NGOs and academics can be crucial for the local communities’ chances of gaining the insights and skills necessary for qualified co-management.

Government agencies

Most developing countries have small government forestry and environment departments with limited personnel and budgets. Usually, the resident staffs in rural areas deal directly with people on behalf of the forestry department. Often, these staff members are less educated than their urban counterparts within the departments. They typically possess less power in terms of decision and policy-making than their urban colleagues, who usually have higher positions in the department hierarchy. This state of affairs means that the following two challenges are particularly critical for forestry departments in many countries to deal with:

- Ensuring that all staff members are well trained and informed in the more technical areas of conservation, management and utilization of forest genetic resources. Moreover, a development towards greater participation in forestry and conservation will require knowledge of participatory approaches and ways to implement them. It is thus crucial that staff members who deal with local communities are trained in these matters.
- Attempting to avoid bureaucratic bottlenecks that hinder problem solution and communication, not only between staff members and local communities, but also between different levels of staff. The success of JFM in India (see Box 5.1) is largely attributed to progressive officials who were allowed by the government administration to institute necessary and fairly radical change (Kumar 2000).

Therefore, whenever possible, forest department personnel should be encouraged to participate in workshops and training courses on participatory methods and to make use of these skills to make a real change. In Hoshangabad, India, printed copies of the government resolution on JFM were distributed to every staff member and training courses were conducted to ensure that all staff understood that JFM was the priority of the forestry department. In Sam Mun, Thailand, university lecturers from a number of academic disciplines were recruited to train government staff and members of different local communities together (see Box 5.5).

Participatory processes are often a combination of cooperation and political struggle. Penan people blocking a timber road in Sarawak, Malaysia. (Ida Theilade/DFSC)

As forest areas increasingly come under the management of local people, the policing duties of forest department staff will be reduced so they can focus on providing high-quality technical advice. As a key stakeholder in forest conservation, the forest department will always need staff qualified to monitor the continuous outcome of participatory conservation of forest genetic resources. Basic components of this procedure include training in forest inventory, yield studies, regeneration surveys, harvest assessments and systems to adjust harvest in case of over-exploitation or destructive harvest methods. But training need not exclude other stakeholders. In Kayan Mentarang (see Box 5.3), for example, a monitoring system based on community resource maps and community-based management systems linked with the findings of the conservation biology team is being developed. Hence, the monitoring programme will combine scientific methods and local knowledge and involve both forest department staff and local communities.

Box 5.5 Participatory land use planning in Thailand

Sam Mun was initially designed as an integrated development project in the highlands of Thailand. The project operates with four development components including local administration, social and economic development, natural resource management and drug control. The project comprises 60 villages of about 12 000 people from five major ethnic groups. Sam Mun covers an area of 18 000 km^2 divided between five districts and two provinces. Substantial parts of the area are under three overlapping protected area legislatures of watershed protection, national park and wildlife sanctuary under the management of the Royal Forest Department (RFD). According to this legislation, forest villagers and ethnic farmers have officially been living and cultivating illegally in the area.

Soon after the onset of the project, efforts aiming at integrating community forestry and local watershed-protection principles began. A tripartite institutional model was set up to combine efforts by Chiang Mai University, the communities, and the RFD. Since then, building institutional capacity has been a key objective of the project. There has been close collaboration between the university and the RFD at both national and regional level. The university provides technical support for research, information and training systems. The main task has been to develop tools for the RFD to understand and incorporate local culture and knowledge, as it is now realized that cross-cultural communication and learning is critical in co-management of watersheds and forest resources. Tools used in the Sam Mun project include:

- A monthly meeting between agencies and government staff as a forum for discussing changing project situations.
- Watershed network committees made up of representatives from both upstream and downstream villages who participate in planning and decision-making.
- Regular and formalized meetings between committees and administrators in order to facilitate quicker communication and shake up old bureaucratic structures.
- Systematic human resource development in order to strengthen stakeholders' capacities for working together throughout planning and implementation. Besides technical areas, conflict management and negotiation have been important components for all officials and newly recruited personnel. Training in such skills has been provided from the very beginning of the project period, partly as classroom lessons and partly as on-the-job training.
- Education of village headmen and district officers to enable them to respond to villagers' initiatives and to aid establishment of self-regulating local institutions. In some areas, NGOs have provided important informal education to assist in leadership development.

The project has experienced rapid changes in local situations and has therefore continuously had to change and improve methods. Consequently, throughout the project period stakeholders have been engaged in a process of training and re-training. A general principle in Sam Mun has been that information is equally shared and accessible to all parties. This principle often requires a simplified form of information, which has been accomplished by visualizing information as much as possible. For example, three-dimensional models of watersheds have been used to assist members of communities in communicating their ideas across cultural and bureaucratic boundaries. Scientific language has been avoided, and local names and meanings preferred. Furthermore, mapping and GIS have been used to monitor the watersheds.

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In Sam Mun, ethnic communities have become watershed co-managers along with different government agencies and units. They have gradually improved the conditions of the watersheds, thus rendering strict enforcement of regulations or community resettlement unnecessary. By incorporating some land-use practices of local ethnic groups, the project has also allowed many groups to maintain their system of land rotation within protected areas. In some sub-districts, the proposals of the local watershed network committee have been consolidated into the sub-district's development plan. Throughout, capacity-building for and with government agencies and local groups alike has been a key to establishing the mutual understanding and collaboration between stakeholders that has enabled the conservation achievements.

Source: Uraiwan (2000)

5.6 Conclusions: some remarks about participatory processes and enabling environments

Natural resource management is increasingly becoming the object of social and political power struggles between different groups claiming interests in specific resources. Today, conservation of forest genetic resources is impossible unless technical expertise is combined with an understanding and consideration of the political and cultural processes within which conservation inevitably takes place. In this chapter, key aspects of these processes have been discussed. It has been argued that successful conservation of forest genetic resources requires the participation of local people and that governments play crucial roles by providing—or, indeed, by not providing—the appropriate institutional and regulatory framework for participatory processes to fully develop.

Many studies show that the optimum formula for forest conservation is joint control and management by governments and local people. Table 5.2 summarizes some of the responsibilities of governments and local communities respectively in regard to participatory conservation processes.

The greatest incentive for local people to look after the forest is the sense that the forest belongs to them. Community Foresters in Tanzania. (Liz Wily)

The notion of power-sharing between people and governments is a delicate and highly complex issue with no easy or universally applicable solution. This chapter has sought to provide some insight into these complexities and illustrate how people in different countries have worked together in order to deal with inevitable problems and conflicts.

A notable feature in many cases is that NGOs have played significant roles as mediators between governments and other stakeholders in forest conservation processes. NGOs differ widely in terms of ideology, political and economic power, and organizational capacity. Like the local communities and states they operate in, NGOs are not homogeneous groups and their interests might diverge. It is therefore not possible to evaluate the role of NGOs *en bloc,* but the fact remains that they often play a critical role in successful negotiation and co-management between people and governments. The presence of capable and environmentally concerned NGOs in itself proves that changes are taking place in many countries as a response to the increasing struggles over natural resources.

Table 5.2 Steps in the participatory process and action requirement

The participatory process	Action required by governments and planners	Action required by local and NGOs
Step 1		
Identification of objectives for conservation of forest genetic resources Inform affected stakeholders	Coordinate agencies and their land use plans Inform affected stakeholders	Be mobilized and organized Disseminate information
Step 2		
Selection of site	Coordinate agencies and their land use plans Inform affected stakeholders	Be mobilized and organized Disseminate information
Step 3		
Stakeholder analysis	Facilitate a forum for discussion with stakeholders	Arrange meetings Listen to all parties concerned
Step 4		
Collection of baseline data	Provide technical expertise and assistance	Participate in data collecting NGOs assist in data collecting at community level
Step 5		
Re-evaluation of objectives for conservation of forest genetic resources and formulation of activity plan done in cooperation with all involved stakeholders	Provide legislation, training, institutional capacity-building	Evaluation of conservation objectives and formulation of conservation project List vital requirements
Step 6		
Identification or establishment of institution or organization responsible for forest management	Facilitate establishment of committee Recognize committee	Agree whether already existing village institution can take up responsibilities or form a new committee Represent all stakeholders Train committee in leadership and management roles
Step 7		
Implementation of planned activities.	Carry out activities Technical advice	Carry out activities Assist if conflict arises
Step 8		
Monitoring of target species	Develop participatory monitoring methods Train community members Advise on how to adjust harvest if not sustainable	Train community members in monitoring Undertake participatory monitoring Decide whether practices have to be changed, and how

INTERNATIONAL APPROACHES AND ACTION

by Pierre Sigaud, Christel Palmberg-Lerche, Alvin Yanchuk and Fernando Patiño Valera

6.1 Introduction

Since the 1990s, and particularly since the United Nations Conference on Environment and Development (UNCED) in 1992, several policy-level international and regional initiatives have been launched and a number of framework instruments established to promote the conservation of biological diversity (including genetic diversity) and the protection and management of forests worldwide. International commitments made by participating countries are progressively being translated at the national level, and policy and principles gradually developed into operational programmes. Policies and programmes relating to forest genetic resources are often closely linked to or strongly influenced by wider perspectives derived from the agricultural, forestry or environmental sectors. This chapter briefly describes the global and regional frameworks that shape forest genetic resources development, and the actions taken at the international level in support of their practical conservation and management.

6.2 National programmes

The preamble of the Convention on Biological Diversity (CBD), adopted in 1992, affirms that states have sovereign rights over their biological and genetic resources, and that they are responsible for conserving their biological diversity and for using their biological resources in a sustainable manner. Many national initiatives covering a wide range of activities, such as inventories, assessments and conservation measures to protect rare and endangered species and populations, regulations governing seed collection and transfer, and comprehensive approaches to the management of landscapes and the restoration of native ecosystems including forests, have an impact on forest genetic resources. Considerations related to forest genetic resources can and have been integrated in a number of countries within wider sectoral or thematic frameworks, such as national forest programmes and biodiversity action plans. The variety of types and ownerships of repositories of genetic resources (for instance protected areas, *in situ* conservation stands, managed forests, clone banks, breeding populations, seed banks), and the need to ensure that they are complementary, constitutes a major organizational, institutional, legal and technical challenge. One frequently identified obstacle to the development or implementation of genetic conservation plans is the undervaluation of the non-monetary value and ecological importance of forests and trees.

Although national-level programmes, when they are in place, provide the basic framework for action in the conservation and management of forest genetic resources, they have a number of technical limitations. For example, the natural distribution of many forest tree species crosses political borders; and some tree species or populations that are of little current importance in their countries of origin have become socially or economically important outside their natural ranges. Such situations raise questions regarding responsibilities for conservation, especially *in situ* conservation. In addition, a number of forest tree introductions, frequently of undocumented origin, have evolved into landraces which are well adapted to environmental conditions in the species' new habitat. These landraces can also be important in genetic conservation activities, and collaboration between two or more countries is therefore necessary to ensure a comprehensiveness and complementarity of *in situ* and *ex situ* activities. In addition, introduction of new germplasm brings a number of biological risks. Hence, there is increasing awareness of the need for consistency in the international regulatory frameworks.

Increasingly, national activities are guided or supported by commitments made at the international level and frequently rely on international or private funds. This creates a challenge for public and private agencies, as well as for the national and international organizations, which need to work together to solve policy, social and technical issues. These include intellectual property rights relating to genetic resources, the sharing of benefits from the use of these resources, the management of biological risks associated with seed movement and the introduction of new biotechnologies, the impact of climate change on forest genetic resources, and many others.

6.3 International developments in forest genetic resource conservation and management

6.3.1 International agreements and processes

The global instruments of direct relevance to forest genetic resources fall under environmental, agricultural or forestry frameworks.

The legally binding Convention on Biological Diversity (CBD) (http://www.biodiv.org), which by June 2004 had been signed by 168 countries, adopted an expanded work programme on forest biological diversity at the Sixth Conference of the Parties in 2002. This broader programme makes specific reference to forest genetic resources and integration of related concerns both in the conservation of biological diversity and in sustainable forest management (see Box 6.1), making it the most comprehensive legally binding international instrument to cover technical, regulatory and property-related aspects of forest genetic resources. An analysis of links between the CBD programme on forest biological diversity and other international forest-related instruments and activities is found in FAO (2003).

The formal inclusion of forest genetic diversity in the work programme of the CBD, including the documentation and management requirements, provides an important vehicle for countries to further justify and strengthen work programmes specifically related to the conservation and management of forest genetic resources.

The legally binding International Treaty on Plant Genetic Resources for Food and Agriculture (ITGRFA) came into force in June 2004 (http://www.fao.org/ag/cgrfa/ itpgr.htm). Central to this Treaty are “the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of benefits derived from their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security.” One of the components of the treaty is the establishment of a multilateral system to facilitate access to plant genetic resources and share benefits in a fair and equitable way. In its present form, the treaty covers the major crop and forage species, listed in an annex to the treaty; the only species of direct relevance to forestry in the multilateral system are members of the genus *Prosopis* (mesquite). However, it potentially covers all plant genetic resources for food and agriculture and thus, according to FAO terminology, also forest genetic resources.

There is no forestry equivalent to the Global Plan of Action for the Conservation and Use of Plant Genetic Resources for Food and Agriculture, which focuses on agricultural crop species. The plan, adopted by the Fourth International Technical Conference on Plant Genetic Resources in Leipzig, Germany in June 1996, makes reference to wild relatives of cultivated plants, often found in forest ecosystems, and to domesticated tree crops such as fruit trees and rubber, but explicitly excludes forest tree genetic resources (FAO 1996a). However, a number

Box 6.1 Excerpt from the Expanded Work Programme on Forests (CBD-COP6/22)

Goal 4: To promote the sustainable use of forest biological diversity

Objective 4

Develop effective and equitable information systems and strategies and promote implementation of those strategies for *in situ* and *ex situ* conservation and sustainable use of forest genetic diversity, and support countries in their implementation and monitoring.

Activities

- Develop, harmonize and assess the diversity of forest genetic resources, taking into consideration the identification of key functional/keystone species populations, model species and genetic variability at the DNA level.
- Select, at a national level, the most threatened forest ecosystems based on the genetic diversity of their priority species and populations and develop an appropriate action plan in order to protect the genetic resources of the most threatened forest ecosystems.
- Improve understanding of patterns of genetic diversity and their conservation *in situ*, in relation to forest management, landscape-scale forest change and climate variations.
- Provide guidance for countries to assess the state of their forest genetic resources, and to develop and evaluate strategies for their conservation, both *in situ* and *ex situ*.
- Develop national legislative, administrative policy measures on access and benefit-sharing on forest genetic resources, taking into account the provisions under Articles 8(j), 10(c), 15, 16 and 19 of the Convention on Biological Diversity and in conformity with future decisions of the Conference of the Parties, as appropriate.
- Monitor developments in new biotechnologies and ensure their applications are compatible with the objectives of the Convention on Biological Diversity with respect to forest biological diversity, and develop and enforce regulations for controlling the use of genetically modified organisms (GMOs) where appropriate.
- Develop a holistic framework for the conservation and management of forest genetic resources at national, subregional and global levels.
- Implement activities to ensure adequate and representative *in situ* conservation of the genetic diversity of endangered, over-exploited and narrow endemic forest species and complement the *in situ* conservation with adequate *ex situ* conservation of the genetic diversity of endangered, over-exploited and narrow endemic species and species of economic potential.

Goal 5: Access and benefit-sharing of forest genetic resources

Objective 1

Promote the fair and equitable sharing of benefits resulting from the utilization of forest genetic resources and associated traditional knowledge.

Activities

Based on the Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization (as adopted by the Conference of

continued

the Parties at its sixth meeting):

- Establish mechanisms to facilitate the sharing of benefits at local, national, regional and global levels.
- Strengthen capacity of indigenous and local communities to negotiate benefit-sharing arrangements.
- Promote dissemination of information about benefit-sharing experiences through the clearing-house mechanism and appropriate means at the local level.

Excerpt from COP6/22—Goals 4 and 5 of the Expanded Work Programme on Forests of the Convention on Biological Diversity (CBD 2003)

of regional initiatives have been initiated to help remedy the situation (see Section 6.4.2 below).

The high-level international forest policy dialogue initiated after UNCED, and now continued through the United Nations Forum on Forests (UNFF), has generated more than 270 proposals for action towards sustainable forest management, which are considered collectively as the IPF/IFF Proposals for Action. The Intergovernmental Panel on Forests (IPF), from 1995 to 1997, and the Intergovernmental Forum on Forests (IFF) from 1997 to 2000, were the main intergovernmental forums for international forest policy development. Although the IPF/IFF proposals for action are not legally binding, participants in these processes are under a political obligation to implement the agreed proposals for action. Thus, each country is expected to conduct a systematic national assessment of the IPF/IFF proposals for action and to plan for their implementation. A few references are made to forest genetic resources, mainly on intellectual property issues.

6.3.2 Global information

A Panel of Experts on Forest Gene Resources, established in 1968, provides advice to FAO, and indirectly to the world community, on programmes and priorities in the field of forest genetic resources. In line with recommendations of the panel, a worldwide information system on forest genetic resources, REFORGEN, has been developed (see Box 6.3). The REFORGEN

Box 6.2 The IPF proposals for action relevant to forest genetic resources

56 (j)

Urged countries to promote fair and equitable sharing of the benefits arising from the utilization of forest genetic resources (as defined by the CBD) and the results and applications of research, upon mutually agreed terms, and to work, as necessary, on addressing issues of the identification of origins of forest genetic resources within their intellectual property rights, *sui generis* or other relevant systems for protection, as appropriate, taking into account the work being advanced by the CBD and other relevant international agreements, in accordance with national laws.

continued

74 (c) IFF

Called upon countries to work with relevant international organizations to help to develop a common appreciation and understanding of the relationship between the intellectual property rights, *sui generis* or other relevant systems for protection, and the CBD, including work, as necessary, on addressing issues related to the identification of origins of traditional forest-related knowledge, and of the knowledge that results from the use of forest genetic resources (as defined by the CBD), with a view to protecting such knowledge from inappropriate use.

85 (b)

The Forum encouraged countries to develop and implement appropriate strategies for the protection of the full range of forest values, including cultural, social, spiritual, environmental and economic aspects; recognition of the multiple functions and sustainable use of all types of forests, with particular regard to biological diversity; participation of communities and other interested parties; integration of the livelihood needs of indigenous and local communities; and planning and management on an ecosystem basis, in which special emphasis should be put on the continued integrity of genetic diversity.

Source: IPF Proposals for Action.
http://www.un.org/esa/forests/pdf/ipf-iff-proposalsforaction.pdf

system includes summarized country-based technical data and information gathered during the preparation of regional workshops on forest genetic resources (see Section 6.4.2).

Many other international, regional and national organizations and institutions have established complementary databases and information systems on forest and tree genetic resources with different focus and purposes. There are, for example, a large number of databases on forest tree taxonomy, nomenclature and botanical description. Global information systems focusing more on forest tree genetic diversity include:

- the Tree Seed Supplier Directory and the Agroforestree Database maintained by ICRAF
- the 2003 IUCN Red List of Threatened Species
- the World Conservation Monitoring Centre's Tree Conservation Database on endangered species
- the CAB Forestry Compendium
- the Organisation for Economic Co-operation and Development (OECD) database on approved basic forest materials, by species and participating country
- Dendrome, the collection of forest tree genome databases maintained by the University of California at Davis
- the World Directory of Forest Geneticists and Tree Breeders compiled by the North American Forestry Commission and the International Union of Forest Research Organizations (IUFRO).

6.3.3 Global instruments related to reproductive materials and the use of biotechnology

The OECD Scheme for Certification of Forest Reproductive Materials Moving in International Trade is a voluntary agreement which encourages the production and use in member countries of forest tree seeds or plants that have been collected, processed, raised, labelled and distributed in a manner that ensures their trueness to name, therefore ensuring their

Box 6.3 REFORGEN: the FAO global information system on FGR

The FAO Worldwide Information System on Forest Genetic Resources (REFORGEN) makes available summarized information on the status of genetic management of important forest trees and shrubs, by country or by species. The system can be used to get a quick overview of the state of diversity at the national, regional and international levels. It can also serve as a primer for more specialized geographic or topical searches. It includes information on:

- institutions dealing with conservation and utilization of forest genetic resources
- main native and introduced tree species and their major uses
- threats to species and populations
- tree species managed for *in situ* conservation
- *ex situ* conservation activities
- tree improvement programmes
- availability of forest reproductive materials for conservation and research purposes.

The REFORGEN information system is available through the Internet on the FAO http://www.fao.org/forestry/foris/reforgen/index.jsp

genetic quality. The scheme was originally created in 1974, and discussions are ongoing to update it and include new categories of materials.

Although the CBD acknowledges that countries have sovereignty over their biological resources as a general principle, a number of regulations have been developed to address concerns over biosafety issues related to the movement of reproductive materials. More specifically, the Cartagena Protocol on Biosafety, under the CBD, deals with the movement across boundaries of living modified organisms. To date, the protocol makes no particular reference to forest tree reproductive material or product.

6.4 Regional initiatives in forest genetic resource conservation and management

6.4.1 Programmes and activities

Cooperation and collaboration can be established for mutual benefit at various levels. Activities may be linked by geographical closeness, ecological similarities or common interest in given species. In some regions, formalized collaborative programmes have been developed to coordinate work among countries. Regional approaches to the conservation of forest biological diversity and forest genetic resources are especially useful when countries have similar institutional conditions, ecological needs and societal requirements.

An example of such voluntary technical regional collaboration is the European Forest Genetic Resources Programme (EUFORGEN), established as follow-up to a resolution of the first Ministerial Conference on the Protection of Forests in Europe, held in Strasbourg, France in 1990. EUFORGEN is coordinated by IPGRI with technical support from FAO. Five networks have been established within the framework of the programme, which supports the development of methodologies and 'best practices' in *in situ* and *ex situ* conservation of genetic variation in targeted pilot species or groups of species, the exchange of reproductive materials for research and conservation purposes and the exchange of information and expertise (Turok and Geburek 2000).

A number of other regional, sub-regional and ecoregional collaborative programmes or projects have been established in Africa, Asia-Pacific and Oceania, the Near East and Central America and Mexico (see Box 6.4). They generally aim at addressing the whole issue of forest genetic conservation and sustainable use from a holistic, inter-sectoral approach. In recent years, regional approaches have been complemented by ecoregional approaches and by action focused on common priority species or groups of species (see examples in Box 6.5).

In addition to these voluntary regional initiatives promoting the conservation and management of the genetic diversity of forest trees, at the technical level there are few comprehensive regional regulations, such as the European Union Directive 1999/105/EC on the marketing and labelling of forest reproductive materials, influencing at least 27 countries (Ackzell 2002).

Box 6.4 Regional programmes and projects on FGR

- The Central America and Mexico Coniferous Resources Cooperative (CAMCORE), hosted by North Carolina State University, Raleigh, USA, deals with the exploration, collection, exchange, testing, improvement and conservation of conifers and some broadleaved species originating in Mexico and Central America (Dvorak 1999).
- The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), under the Secretariat of the Pacific Community, has helped develop comprehensive strategies and coordinated action in five island countries, namely Fiji, Samoa, Solomon Islands, Tonga and Vanuatu (Thomson 2000).
- The Central Asian and Transcaucasian Network on Plant Genetic Resources (CATCN-PGR), focuses on the conservation of genetic resources of crops and forest trees in eight countries of the sub-region. It benefited during its establishment from the experience and assistance of IPGRI and the EUFORGEN programme (Turok 1997).
- The Sub-Saharan African Programme on Forest Genetic Resources (SAFORGEN) coordinated by IPGRI in collaboration with FAO, aims at strengthening regional and national research institutes and forest research programmes in countries in sub-Saharan Africa (Eyog Matig and Gaoué 2002).
- The Asia Pacific Association of Forest Research Institutions (APAFRI) and IPGRI have collaborated to establish the Asia Pacific Forest Genetic Resources Programme (APFORGEN). This programme aims to strengthen regional collaboration on forest genetic resources and increase conservation and sustainable use of tropical forest genetic resources in the region (Luoma-Aho *et al.* 2003).
- The North American Forestry Commission, which is one of six forest commissions established by FAO, has established a Working Group on Forest Genetic Resources which promotes the collection, exchange, and dissemination of information. Most of the efforts over the past few years have been to help coordinate research, training and international exchange on forest genetic resource management know-how between Mexico, USA and Canada.

Box 6.5 Species-specific FGR networks

A number of past and ongoing initiatives have targeted certain important tree species. These include the regional EUFORGEN programme mentioned above, in which species-specific networks have been established under a regional umbrella. The examples below simply point to a few cases where national and international programmes have specifically addressed the forest genetic resource issues for a species:

- The Project on Genetic Resources of Arid and Semi-Arid Zone Arboreal Species for the Improvement of Rural Living, coordinated by FAO in the 1980s and 1990s, focused on the exploration, collection, exchange, evaluation and conservation of genetic resources of dry-zone multipurpose species, with special reference to *Acacia* and *Prosopis* spp. (Graudal 1995; see also www.dfsc.dk; Ræbild *et al.* 2003 a-u; Ræbild et al. 2004 a-e; FAO 2004).
- The International Neem Network, coordinated by FAO, aims to clarify the extent and patterns of genetic variation of *Azadirachta indica* and to help collaborating countries in Asia, Africa and Latin America to make appropriate use of the potential that this multipurpose species offers in arid lands (Hansen *et al.* 1996; FAO 1998).
- LEUCNET is an informal network of scientists, extensionists and tree growers who share a common interest in improving the productivity and utility of *Leucaena* spp. (FAO, 1995).
- TEAKNET, focusing on *Tectona grandis*, is hosted by the Forest Department of Myanmar, with close links to FAO's Regional Office for Asia and the Pacific, Bangkok, Thailand (FAO 1996b).
- The International Network for Bamboo and Rattan (INBAR) has its headquarters in Beijing, China (INBAR 2003).
- The International Poplar Commission (IPC), one of FAO's technical Statutory Bodies, aims to promote the cultivation, conservation and utilization of members of the family *Salicaceae*, which includes poplars and willows. The IPC now comprises 37 member countries (Ball 1997).
- IPGRI established COGENT in 1992 to improve the sustainable production of coconut and to promote a worldwide programme for the conservation and use of coconut genetic resources (IPGRI 1999). At present, COGENT has 38 member countries that collaborate in coconut research and gene conservation (Ramanatha Rao and Batugal 1998).
- The global IPGRI/International Cocoa Organization (ICCO) project entitled 'Cocoa germplasm utilization and conservation' has established collaboration among countries that have the original native populations, as well as countries in West Africa and South-east Asia (Eskes *et al.* 2000).

More recent initiatives include a number of genome sequencing projects on *Eucalyptus* and *Populus*.

Table 6.1 Workshops on FGR supported by FAO, IPGRI or DFSC from 1995 to 2003

Eco-region	International organizers	National organizer	Number of countries/ territories covered	Country status on FGR	List of national priority species	Regional summary or synthesis	Regional action plan or recommen-dations
Temperate North America (1995)	North American Forestry Commission	USDA Forest Service U. California	3		+	+	+
Boreal forests (1995)	FAO	Canadian Forest Service	20		+ +	+ +	+ +
Sahelian Africa (1998)	FAO, IPGRI, DFSC, ICRAF, IUFRO	CNSF, Burkina Faso	15	+	+	+	+
Pacific Islands (1999)	SPRIG, AusAID, FAO, SPC, SPREP, IUFRO	Samoa Forestry Division	18	*	+	+	+
Eastern and Southern Africa (2000)	SADC, FAO, ICRAF, IPGRI, DFSC, IUFRO	Forestry Division, Tanzania	9	+	+	+	+
South-east Asia (2001)	FORGENMAP, APAFRI, DFSC, FORSPA	Thai Royal Forestry Department	8	+	+	+	+
Central America (2002)	FAO, IPGRI, IUFRO	CATIE, Costa Rica	9	+	+	+	*
Central Africa (2003)	FAO, ATO, UNDP, IPGRI, ICRAF, IUFRO	Direction des forêts, Congo	6	*	+	+	*
South Asia (2003)	APFORGEN, IPGRI, APAFRI, FAO, DFSC	FRIM Malaysia	13	+	+	+	+

* work in progress, + work completed

Note: in Europe, the European Forest Genetic Resources Programme (EUFORGEN) has been coordinating country-based action on forest tree genetic diversity since 1994.

From Patiño (2004)

6.4.2 Regional forest genetic resources status and action plans

Following the Leipzig Conference (see Section 6.3.1), a number of workshops on forest genetic resources have been convened with the support of FAO, IPGRI, the Danida Forest Seed Centre (DFSC) and other organizations. These regional and sub-regional workshops have supported the development of status reports and action plans for the conservation and sustainable use of forest genetic resources within a regional framework (see Table 6.1). During the preparation of these workshops, a number of methodologies for assessing the state of the genetic diversity of forest trees and shrubs at country level were developed by local experts. In most regions covered, country-based status reports have been prepared, synthesized in regional action plans, as deemed useful by participants. Workshops have been held for North American Temperate Species (1995), Boreal Forests (1995), Sahelian Africa (1998), the South Pacific (1999), Southern and Eastern Africa (2000), South-east Asia (2001), Central America, Cuba and Mexico (2002), Asia (2003) and Central Africa (2003) (Patiño, 2004). Updated information on species and institutions has been compiled in the FAO Worldwide Information System on Forest Genetic Resources (REFORGEN) (see Section 6.3.2 and Box 6.3).

6.5 Concluding remarks

International priorities in forest genetic resources have changed from an early focus on support to countries for genecological studies and seed collection underpinning species and provenance research of a few major timber species in the 1960s and early 1970s, to the wider management of genetic resources of a range of trees and shrubs for a great number of purposes and end uses, in a variety of national and local contexts. Such a shift, due largely to changes in the perception of the place and role of forests and trees in national development, has been accompanied by increased attention in all countries to native species. At the policy level, national and international agendas are increasingly dealing with issues relating to intellectual property rights and patenting of genetic applications, access and benefit sharing in the use of genetic materials, and regulations over biotechnology products and processes, such as genetic engineering (Lewontin and Santos 1997). These developments are often led by, and under the umbrella of, agreements in other sectors, including trade and economics, agriculture, and the environment, rather than being integral parts of forestry-led initiatives.

Furthermore, the number of instruments related to forests, forestry and forest genetic resources have recently greatly increased at both national and international level in response to increased environmental awareness and related national and international agreements and programmes. There is a need to ensure close collaboration between such instruments, including cross-sectoral links. As institutions and expertise in developing countries have gradually become stronger, international action has over the past decade increasingly stressed institutional networking rather than direct support, and FAO, IPGRI and other international and bilateral institutions have shifted their attention to building technical partnerships with national institutions in developed and developing countries. The European IPGRI/EUFORGEN programme provides an excellent example and a possible model for other regions in collaborative decision-making and implementation of national action plans carried out under a regional umbrella.

Globally, increased movement of people, goods, services, information and know-how contributes to a constant change in demands on forests, wood and non-wood products and environmental services, and to shifts in the boundaries in, and priorities of, the forest genetic resources sector. The availability of up-to-date information, as stressed in the CBD and in the ITPGRFA, is essential for the decision-maker, the manager and the scientist. What type of forest resource or function will be used, for which purpose, by which customer, in which region, over which period, are important parameters that will condition the perception of forest genetic resources as well as the degree of attention given to this issue.

REFERENCES

Ackzell, L. 2002. On the doorstep to new legislation on forest reproductive material: policy framework and legislation on trade with forest reproductive material. Forest Genetic Resources 30:52–53.

Adnan, S. (ed.). 1992. People's participation, NGOs and the flood action plan: an independent review. Oxfam, Dhaka, Bangladesh.

Anan Ganjanapan, A. 1996. The politics of environment in Northern Thailand: ethnicity and highland development programs. Pp. 202–212 *in* Seeing forests for trees. Environment and environmentalism in Thailand (P. Hirsch, ed.). Silkworm Books, Chiang Mai, Thailand.

Ayling, R. and K. Kelly. 1997. Dealing with conflict: natural resources and dispute resolution. Commonwealth For. Rev. 76(3):182–185.

Ball, J. 1997. News from the International Poplar Commission. Forest Genetic Resources 25:68–69.

Barth, F. 1993. Balinese worlds. University of Chicago Press, Chicago, USA.

Bawa, K.S. 1994. La selva: ecology and natural history of a tropical rain forest. University of Chicago Press, Chicago, USA.

Bawa, K. S. and Hadley, M. (eds.). 1990. Reproductive ecology of tropical forest plants. Man and the Biosphere Series Vol. 7, UNESCO, Paris, IUBS and Parthenon Publishing Company.

Benson, D.H. 1985. Aspects of the ecology of a rare tree species, *Eucalyptus benthamii*, at Bents Basin, Wallacia. *Cunninghamia* 1:371-383.

Boffa, J.M. 2000. West African agroforestry parklands: keys to conservation and sustainable management. Unasylva 51:11–17

Boshier, D. H. 2000. Mating systems. Pp. 63–79 *in* Forest conservation genetics (A. Young, D. Boshier and T. Boyle, eds.) CSIRO and CABI Publishing, Wallingford, UK.

Bourdieu, P. 1990. The logic of practice. Polity Press, Cambridge, UK.

Bourdieu, P. 1991. Language and symbolic power. Polity Press, Cambridge, UK.

Boyle, T.J.B. and B. Boontawee (eds.). 1995. Measuring and monitoring biodiversity in tropical and temperate forests. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Brown, S. and S. Kresovich. 1996. Molecular characterization for plant genetic resources conservation. Pp. 85–93 *in* Genomic mapping in plants (A.H. Paterson, ed.). R.G. Landes Austin, TX, USA.

Buckles, D. (ed.). 1999. Cultivating peace. Conflict and collaboration in natural resource management. International Development Research Centre, Ottawa, Canada.

Buckles, D. and G. Rusnak. 1999. Conflict and collaboration in natural resource management. Introduction *in* Cultivating peace. Conflict and collaboration in natural resource management (D. Buckles, ed.). International Development Research Centre, Ottawa, Canada.

Butcher, P.A., J.C. Glaubitz and G.F. Moran. 1999. Applications for microsatellite markers in the domestication and conservation of forest trees. Forest Genetic Resources 27:34–42.

Butterfield, R.P. 1995. Promoting biodiversity: advances in evaluating native species for reforestation. For. Ecol. Manage. 75:11–121.

CBD. 2003. Handbook of the Convention on Biological Diversity, 2nd edition. Secretariat of the CBD, Montreal, Canada.

CCB. 1995. Survey of national teak forests in Thailand. Centre for Conservation Biology, Mahidol University and Royal Forest Department. Report to the World Bank, Bangkok, Thailand.

Chambers, R. 1992. Rural appraisal: rapid, relaxed and participatory. Discussion Paper 311, Institute of Development Studies, University of Sussex, UK.

Danida. 1996. Logical framework approach. A flexible tool for participatory development. Danida, Copenhagen, Denmark.

Darrow, W.K. 1995. Selection of eucalypt species for cold and dry areas in South Africa. Pp. 336–338 *in* Eucalypt Plantations: Improving Fibre Yield and Quality. Proceedings of CRCTHF—IUFRO Conference, Hobart, 19–24 Feb. Co-operative Research Centre for Temperate Hardwood Forestry, Hobart, Australia.

Davis, R. 1984. Muang metaphysics: a study of Northern Thai myth and ritual. Pandora, Bangkok.

Davis-Case, D. 1989. Community forestry, participatory assessment, monitoring and evaluation. FAO of the United Nations, Rome, Italy.

Davis-Case, D. 1990. The community's toolbox. The idea, methods and tools for participatory assessment, monitoring and evaluation in community forestry. Community Forestry Field Manual 2, FAO of the United Nations, Rome, Italy.

Dawson, I. and J. Were. 1999. *Prunus africana: ex, circa*, and *in situ* conservation of an endangered medicinal tree: a case study for conservation. Pp. 121–128 *in* Recent research and development in forest genetic resources. Proceedings of the Training Workshop on the Conservation and Sustainable Use of Forest Genetic Resources in Eastern and Southern Africa, 6-11 December 1999, Nairobi, Kenya.

Dreistadt, S.H., D.L. Dahlsten, and G.W. Frankie. 1990. Urban forests and insect ecology. BioScience 40(3):192–198.

Dvorak, W.S. 1999. Recent activities of the CAMCORE cooperative. Forest Genetic Resources 27:73–74.

Eghenter, C. 2000. Mapping people's forests: The role of mapping in planning community-based management of conservation areas in Indonesia. Biodiversity Support Program, Washington, DC, USA.

El-Kassaby Y.A., and G. Namkoong. 1995. Genetic diversity of forest tree plantations: consequences of domestication. Pp. 218–228 *in* Consequences of changes in biodiversity, IUFRO World Congress 2, Tampere, Finland.

Ellen, R. 1986. What Black Elk left unsaid. Anthropol. Today 2(6):8–12.

Eriksson, G., G. Namkoong and J.H. Roberds. 1993. Dynamic gene conservation for uncertain futures. For. Ecol. Manage. 62:15–37.

Eskes, A.B., J.M.M. Engels, and R.A. Lass (eds.). 2000. Working procedures for cocoa germplasm evaluation and selection. Proceedings of the CFC/ICCO/IPGRI Project Workshop, 1–6 February 1998, Montpellier, France.

Eyog Matig O. and O.G. Gaoué (eds.). 2002. Development of appropriate conservation strategies on African forest species identified as priority species by SAFORGEN member countries. IPGRI, Nairobi, Kenya.

Falconer, D.S. 1989. Introduction to quantitative genetics, (3rd edition). Longman, London.

FAO. 1989. Plant genetic resources: their conservation *in situ* for human use. FAO of the United Nations, Rome, Italy.

FAO. 1993. Conservation of forest genetic resources in tropical forest management: principles and concepts (based on the work of R.H. Kemp, G. Namkoong and F.H. Wadsworth). Forestry Paper No. 107, FAO of the United Nations, Rome, Italy.

FAO. 1994. The role of alternative conflict management in community forestry. Forest, Trees and People programme, Working Paper No. 1, FAO of the United Nations, Rome, Italy.

FAO. 1995. LEUCNET news: the newsletter of the international *Leucaena* research and development network. Forest Genetic Resources 23:25.

FAO. 1996a. The 4th International Technical Conference on Plant Genetic Resources and follow-up on forest genetic resources. Forest Genetic Resources 24:40–42.

FAO. 1996b. TEAKNET. Forest Genetic Resources 24:63.

FAO. 1998. Activities of the International Neem Network. Forest Genetics Resources 26:30.

FAO. 1999. Report of the Eleventh Session of the FAO Panel of Experts on Forest Genetic Resources. 29 September–1 October 1999, FAO of the United Nations, Rome, Italy.

FAO. 2002. Criteria and indicators for assessing the sustainability of forest management: conservation of biological diversity and genetic variation. Document prepared by G. Namkoong, T. Boyle, Y. A. El-Kassaby, C. Palmberg-Lerche, G. Eriksson, H.-R. Gregorius, H. Joly, A. Kremer, O. Savolainen, R. Wickneswari, A. Young, M. Zeh-Nlo and R. Prabhu. Forest Genetic Resources Working Paper FGR/37E, FAO of the United Nations, Rome. Italy.

FAO. 2003. International policy debate on forests and forest biological diversity. Pp. 45-49 *in* State of the world's forests 2003, Section I. FAO of the United Nations, Rome, Italy.

FAO. 2004. International Species and Provenance Trials of Dry-zone Acacia and Prosopis Species: Results from the 1990–1994 assessments. Forest Genetic Resources 31:38.

Fourré, J.L., P. Berger, L. Niquet and P. Andre. 1997. Somatic embryogenesis and somaclonal variation in Norway spruce: morphogenetic, cytogenetic and molecular approaches. Theor. Appl. Genet. 94:159–169.

Frankel, O.H. 1976. Natural variation and its conservation. Pp. 21–44 *in* Genetic diversity in plants (A. Muhammed, R. Aksel and R.C. von Borstel, eds.) Plenum Press, New York, USA.

Frankel, O.J. and M.E. Soulé. 1981. Conservation and evolution. Cambridge University Press, Cambridge, UK.

Franklin, I.R. 1980. Evolutionary change in small populations. Pp. 135–149 *in* Conservation biology: an evolutionary-ecological perspective (M.E. Soulé and B.A. Wilcox, eds.). Sinauer Associates, Sunderland, MA, USA.

Franzel, S., H. Jaenicke and W. Janssen. 1996. Choosing the right tree: setting priorities for multipurpose tree improvement. ISNAR Research Report No 8, International Service for National Agricultural Research, The Hague, The Netherlands.

FSIV. 1996. List of native Vietnamese tree species with high value timber. Paper presented at meeting in Hanoi, 21 November 1999. Forest Science Institute of Viet Nam and STRAP (CGP/RAS/142/JPN).

Gardner, K. and D. Lewis. 1996. Anthropology, development and post-modern challenge. Pluto Press, London, UK.

Ghazoul, J. and M. McLeish. 2001. Reproductive ecology of tropical forest trees in logged and fragmented habitats in Thailand and Costa Rica. Plant Ecol. 153:335–345.

Gillet, E.M. (ed.). 1999. Which DNA marker for which purpose? Final compendium of the research project developments, optimization and validation of molecular tools for assessment of biodiversity in forest trees in the European Union DGXII Biotechnology FW IV Research Programme 'Molecular Tools for Biodiversity'. Institut für Forstgenetik und Forstpflanzenzüchtung, University of Göttingen, Germany.

Granhof, J. 1998. Conservation of forest genetic resources without people's participation—an experience from Northeast Thailand. Royal Forest Department (RFD) and Forest Genetic Resources Conservation and Management Project (FORGENMAP), Bangkok, Thailand.

Graudal, L. 1995. Progress in the evaluation of field trials established within the framework of the FAO project on genetic resources of arid and semi-arid zone arboreal species. Forest Genetic Resources 23:56–57.

Graudal, L. and E.D. Kjær. 2000. Can national tree seed programmes generate economic, social and/or environmental benefits to cover their costs? Considerations on economics, sustainability and challenges ahead for tree seed centres in tropical countries. Pp. 15–28 *in* 2001. Recent Research and Development in Forest Genetic Resources (O. Eyog-Matig, B. Kigomo and J.-M. Boffa, eds). Proceedings of the Training Workshop on the Conservation and Sustainable Use of Forest Genetic Resources in Eastern and Southern Africa, 6–11 December 1999, Nairobi, Kenya. International Plant Genetic Resources Institute, Nairobi, Kenya.

Graudal, L., E.D. Kjær, and S. Canger. 1995. A systematic approach to the conservation of genetic resources of trees and shrubs in Denmark. For. Ecol. Manag. 73:117–134.

Graudal, L., E.D. Kjær, A. Thomsen and A.B. Larsen. 1997. Planning national programmes for conservation of forest genetic resources. Technical Note No. 48, Danida Forest Seed Centre, Humlebæk, Denmark.

Graudal, L., E.D. Kjær, V. Suangtho, P. Saardavut and A. Kaosa-ard. 1999. Conservation of genetic resources of teak (*Tectona grandis*) in Thailand. Technical Note No. 52, Danida Forest Seed Centre, Humlebæk, Denmark.

Grimble, R., M-K. Chan, J. Aglionby and J. Quan. 1995. Trees and trade-offs: a stakeholder approach to natural resource management. Gatekeeper Series No. 52, Sustainable Agriculture Programme, International Institute for Environment and Development, London, UK.

Guldager, P. 1975. *Ex situ* conservation stands in the tropics. Pp. 85–92 *in* The methodology of conservation of forest genetic resources. FO:MISC/75/8. FAO of the United Nations, Rome.

Hamann, A., S.N. Aitken, and A.D. Yanchuk. 2004. Cataloguing *in situ* protection of genetic resources for major commercial forest trees in British Columbia. Pp. 295-305 *in* Conference proceedings, Dynamics and Conservation of Genetic Diversity in Forest Ecosystems, Strasbourg, 2–5 December 2003. For. Ecol. Manag. 197 (1–3).

Hamrick, J.L. 1994. Genetic diversity and conservation in tropical forests. *In* Proceedings of the International Symposium on Genetic Conservation and Production of Tropical Forest Tree Seed. ASEAN-Canadian Forest Tree Seed Centre Project, Muak-Lek, Saraburi, Thailand.

Hamrick, J.L. 2001. Breeding patterns of a tropical dry forest tree species, *Enterolobium cyclocarpum*, in disturbed and undisturbed habitats. Pp. 291–294 *in* Tropical ecosystems: structure, diversity and human welfare (K.N. Ganeshaiah, R. Uma Shaanker and K.S. Bawa, eds.). Oxford and IBH Publishing Co., New Delhi, India.

Hamrick, J.L. and M.J. Godt. 1990. Allozyme diversity in plant species. Pp. 43–63 *in* Plant population genetics, breeding, and genetic resources (A.H.D. Brown, M.T. Clegg, A.L. Kahler and B.S. Weir, eds.). Sinauer Associates, MA, USA.

Hamrick, J. L. and J. D. Nason. 2000. Gene flow in forest trees. Pp 81–90 *in* Forest conservation genetics (A. Young, D. Boshier and T. Boyle, eds.) CSIRO and CABI Publishing, Wallingford, UK.

Hansen, C.P. and E.D. Kjær. 1999. Appropriate planting material in tree plantings: opportunities and critical factors. Pp. 53–71 *in* Proceedings of the International Expert Meeting on the Role of Planted Forests for Sustainable Forest Development, Santiago, Chile, 6–9 April 1999.

Hansen, C.P., Thomson, A. and O. Souvannavong. 1996. Recent activities of the International Neem Network. Forest Genetic Resources 24:33–39.

Hirsch, P., K. Phanvilay, and K. Tubtim. 1999. Nam Ngun, Lao PDR. Community-based natural resource management and conflicts over watershed resources. Pp. 45-59 *in* Cultivating peace. Conflict and collaboration in natural resource management (D. Buckles, ed.). International Development Research Centre, Ottawa, Canada.

Hodgkin, T. 1996. Some current issues in conserving the biodiversity of agriculturally important species. Pp. 357–368 *in* Biodiversity, science and development (F. di Castri and T. Younès, eds.). IUBS, CAB International, Wallingford, UK.

Hubbell, S.P. and R.B. Foster. 1990. The fate of the juvenile trees in a Neotropical forest: Implications for the natural maintenance of tropical diversity. Pp. 317–341 *in* Reproductive ecology of tropical forest plants (K.S. Bawa and M. Hadley, eds.). Man and the Biosphere Series Vol. 7, UNESCO, Paris, IUBS and Parthenon Publishing Company.

Hyppa, J., H. Huupa, M. Inkinen and M. Engdahl. 1998. Verification of the potential of various remote sensing data sources for forest inventory. Pp. 1812–1814 *in* Proceedings of the IEEE Geosciences and Remote Sensing Society, Seattle, WA, 6–10 July 1998. Institute of Electrical and Electronics Engineers, Piscataway, NJ, USA.

INBAR. 2003. INBAR in China and the World—Proceedings of the International Conference on INBAR in China and the World. International Network for Bamboo and Rattan (INBAR), Beijing, China.

IPGRI. 1999. International Coconut Genetic Resources Network (COGENT) Newsletter. IPGRI, Rome, Italy.

Isager, L. 2001. People and history of North Thailand. Chapter 8 *in* Forest in culture, culture in forest. E. Poulsen et al., eds.). Research Centre on Forest and People in Thailand, Danish Institute of Agricultural Sciences Research Centre, Foulum, Denmark.

IUCN. 2003. The 2003 IUCN red list of threatened species. www.redlist.org

Jacobsen, N.K. 1976. Natural Geographical Regions of Denmark. Geogr. Tidsskr. 75:1-7. Det Kongelige Danske Geografiske Selskab.

Jain, S.M. and K. Ishii (eds.). 2003. Micropropagation of woody plants and fruits. Kluwer Academic Publishers, Dordrecht, The Netherlands.

James, F.C. 1999. Lessons learned from a study of habitat conservation planning. Bioscience 49(11):871–874.

Jarvis, D.I., L. Myer, H. Klemick, L. Guarino, M. Smale, A.H.D Brown, M. Sadiki, B. Sthapit and T. Hodgkin. 2000. Crop population genetics and breeding (mating) systems. Pp. 72–94 *in* A training guide for *in situ* conservation on-farm (version 1). IPGRI, Rome, Italy.

Jensen, A. 2000. Stratégie nationale intégrée de production et de diffusion des semences des espéces lignesuses au Burkina Faso. CNSF, Burkina Faso/Danida Forest Seed Centre, Denmark.

Karku, A., P. Hurme, M. Karjalainen, P. Karvonen, K. Kärkkäinen, D. Neale and O. Savolainen. 1996. Do molecular markers reflect patterns of differentiation in adaptive traits of conifers? Theor. Appl. Genet. 93:215–221.

Karp, A. 2000. The new genetic era: will it help us in managing genetic diversity? SAT 21 Meeting, IPGRI, FRIM, Kuala Lumpur, Malaysia.

Kjær, E.D. and I. Nathan 2000. Integrated use and conservation of forest genetic resources. *In* Proceedings of the international workshop on experiences with ICD in natural resource management, Eigtved Pakhus, Copenhagen, September 2000. Reprint available from Danida Forest Seed Centre, Humlebæk, Denmark.

Koshy, M.P., G. Namkoong, P. Kageyama, A. Stella, F. Gandara and W.A.N. Amaral. 2002. Decision-making strategies for conservation and use of forest genetic resources. Pp. 263–275 *in* Managing plant genetic diversity (J.M.M. Engels, V. Ramantha Rao, A.H.D. Brown and M.T. Jackson, eds.). IPGRI, Rome, Italy and CABI, Wallingford, UK.

Kuata, D.A., P. Pupuka and G. Rosoman. 1996. Village-based forest harvesting in Solomon Islands. Paper presented to South Pacific Heads of Forestry Meeting, Port Vila, Vanuatu, 23–28 September 1996.

Kumar, N. 2000. All is not green with JFM in India. Forest, Trees and People Newsletter 42:46–50.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455–1460.

Lande, R. and G.F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pp. 878–124 *in* Viable populations for conservation (M.E. Soule, ed.), University of Chicago Press, Chicago, USA.

Lawrence, D., D. Peart and M. Leighton. 1998. The impact of shifting cultivation on a rainforest landscape in West Kalimantan: spatial and temporal dynamics. Landscape Ecol. 12:135–148.

Ledig, F.T. 1992. Human impacts on genetic diversity in forest ecosystems. Oikos 63:87–108.

Lehane, R. 1994. Endangered eucalypt with commercial prospects. Onwood, Autumn 1994:6. CSIRO Forestry and Forest Products, Clayton, Victoria, Australia.

Lewontin. R. and M. Santos. 1997. Current trends in intellectual property rights protection pose serious threats to future innovations in agricultural sector. Diversity 13(2/3):25–27.

Libby, W.J. 1987. Genetic resources and variation. Pp. 200-209 *in* Forest trees in improving vegetatively propagated crops. Academic Press, New York, USA.

Lillesøe, J.-P. B. 1996. Dipterocarps. A review of literature of relevance to tree seed source programmes with emphasis on the species in Malesia (2nd, slightly revised edn). Ministry of Forestry, Indonesia Tree Seed Source Development Project. P.T. Ardes Perdana/Danagro Adviser A/S, Jakarta, Indonesia.

Lund, S. 1999. Etablissement des formes de collaboration avec les populations locales. Rapport technique pour le projet ‘Production de semences et conservation des ressources forestières dans les territoires villageois’. Centre national de Semences Forestières, Burkina Faso/Danida Forest Seed Centre, Denmark.

Luoma-Aho, T., L.T. Hong, V. Ramanatha Rao, and H.C. Sim (editors). 2003. Forest genetic resources conservation and management: Proceedings of the Asia Pacific Forest Genetic Resources Programme (APFORGEN) Inception Workshop, Kepong, Kuala Lumpur, Malaysia,15–18 July 2003.

Lynch, M. 1996. A quantitative-genetic perspective on conservation issues. Pp. 471–501 *in* Conservation genetics: case studies from nature (J.C. Avise, and J.L. Hamrick, eds.). Chapman & Hall, New York, USA.

Lynch, M. and B. Walsh. 1998. Genetics and analysis of quantitative traits. Sinauer Associates, Sunderland, MA, USA.

Mahapol, S. 1954. Teak in Thailand. Royal Forest Department, Bangkok, Thailand.

Mendonza, L. 1983. Notes on *Eucalyptus benthamii* in Argentina. *In* Proceedings of ‘Colloque International Sur Les Eucalyptus Resistants Au Froid’. Bordeaux, France, September, 1983.

Milton, K. 1996. Environmentalism and cultural theory. Routledge, London, UK.

Namkoong, G. 1984a. A control concept for gene conservation. Silvae Genet. 33:160–163.

Namkoong, G. 1984b. Strategies for gene conservation in tree breeding. Pp. 93–109 *in* Proceedings of Plant Genetic Resources. A Conservation Imperative Symposium (C.W. Yeatman, D. Kafton, G. Wilkes, eds.). Westview Press, Boulder, CO, USA.

Namkoong, G. 1998. Genetic diversity for forest policy and management. Pp. 30–44 *in* The living dance: policy and practices for biodiversity in managed forests (F.L. Bunnel and J.F. Johnson, eds.). UBC Press, Vancouver, Canada.

Namkoong, G. 2001. Forest genetics: pattern and complexity. Can. J. For. Res. 31(4):623–632.

Namkoong, G., T. Boyle, H-R. Gregorius, H. Joly, O. Savolainen, W. Ratnam and A. Young. 1997. Testing criteria and indicators for assessing the sustainability of forest management: genetic criteria and indicators. Working Paper No. 10, Centre for International Forest Research (CIFOR), Bogor, Indonesia.

National Academy of Sciences. 1991. Managing global genetic resources: forest trees. National Academy Press, Washington, DC, USA.

Nikiema, A., D. Poda and M. Ouedraogo. 1997. Inventaire et cartographie des peuplements naturels de *Acacia senegal* (L.) Willd. au Burkina Faso. Rapport Technique No. 23, Projet 7 ACP BKF/031, CNSF, Burkina Faso.

Nordisk Ministerråd. 1984. Naturgeografisk regioninddeling af Norden, Nordiska Ministerrådet.

Ødum, S. 1968. Udbredelsen af træer og buske i Danmark (English summary: The distribution of trees and shrubs in Denmark). Bot. Tidsskr., 64(1). Dansk Botanisk Forening, København.

Owens, J.N. 1994. Biological constraints to seed production in tropical trees. Pp. 40–51 *in* Proceedings of the International Symposium on Genetic Conservation and Seed Production of Tropical Forest Tree Seeds (R.M. Drysdale, S.E.T. John and A.C. Yapa, eds.). ASEAN–Canadian Seed Center, Muaklek, Thailand.

Palmberg-Lerche, C. 2000. International action in the management of forest genetic resources: status and challenges. Working Paper FGR/1. Forest Resources Division, Forestry Department, FAO, Rome, 49 pp.

Palmberg-Lerche, C., J. Turok, and P. Sigaud. 2004. Conservation and Management of Forest Genetic Resources in Europe: Contributions of a Training Course (Geburek, Th. and J. Turok eds.), Gmunden, Austria, 30 April–11 May 2001. Arbora Publishers, Slovakia (in press).

Patiño, F. 2004. Progress in country and regional assessments of forest tree genetic diversity. Forest Genetic Resources 31:57–60.

Poffenberger, M. 2000. Communities and forest management in Southeast Asia. A regional profile of the Working Group on Community Involvement in Forest Management, IUCN, Gland, Switzerland.

Purvis, A. and A. Hector. 2000. Getting the measure of biodiversity. Nature 405: 212–219.

Ræbild, A. et al. 2003a–u. Evaluation of field trials in the Arid Zone Series. Trials nos. 1–15, 19–24. Results and documentation Nos. 2–15, 22, 23, 25–28, and 33. Danida Forest Seed Centre.

Ræbild, A. et al. 2004a–e . Evaluation of field trials in the Arid Zone Series. Trials nos. 16–18, 25–26. Results and documentation Nos. 24, 29–32. Danida Forest Seed Centre/Forest & Landscape Denmark.

Rahnema, M. 1992. Participation. Pp. 116–32 *in* The development dictionary: a guide to knowledge as power (W. Sachs, ed.). Zed Press, London.

Ramanatha Rao, V. and P. Batugal (eds.). 1998. Proceedings of the COGENT regional coconut genebank planning workshop, Pekanbaru, Riau, Indonesia, 26–28 February 1996.

Ritland, K. and S. Jain. 1981. A model for the estimation of outcrossing rate and gene frequencies using n independent loci. Heredity 47:35–52

Roche, L. and M.J. Dourojeanni. 1984. A guide to in situ conservation of genetic resources of tropical woody species (prepared within the framework of FAO/UNEP Project 1108-75-05, 'Conservation of Forest Genetic Resources'). FAO of the United Nations, Rome, Italy.

Savolainen, O. and K. Karkkainen. 1992. Effect of forest management on gene pools. New For. 6:329–345.

Saxena, N.C. 1999. The New Forest Policy and Joint Forest Management in India, Pre-Workshop Volume, National Workshop on JFM, 25–26 Feb, organized by VOKSAT, SPWD, AKF and Gujrat Forest Department, Ahmedabad, India.

Schmidt, L. 2000. Guide to handling of tropical and subtropical forest seed. Danida Forest Seed Center, Humbelæk, Denmark.

Shaffer, M. 1981. Minimum population sizes for species conservation. BioScience 31:131–134.

Shepherd, G. 1992. Managing Africa's tropical dry forests: a review of indigenous methods. ODI Agricultural Occasional Paper 14, Overseas Development Institute, London, UK.

Shiva, V. 1988. Staying alive: women, ecology and development. Zed Press, London, UK.

Singh, S. 1996. Joint Forest Management in India. Pp. 29–40 *in* Decentralization and biodiversity conservation (E. Lutz and J. Caldecott, eds.). World Bank, Washington, DC, USA.

Smouse, P.E. 1998. To tree or not to tree. Mol. Ecol. 7:399–412.

Smouse, P.E. and C. Chevillon 1998. Analytical aspects of population-specific DNA-fingerprinting for individuals. J. Heredity 89:143–150.

Soerianegara, I. and R.H.M.J. Lemmens (eds.). 1994. Plant resources of southeast Asia; Timber trees: major commercial timbers, Vol. 5, No. 1. PROSEA, Bogor, Indonesia/Backhuys Publishers, Leiden, The Netherlands.

Stott, P. 1991. Muang and Pa. Elite views of nature in Thailand. Pp. 142–154 *in* Thai construction of knowledge (Manas Chitakasem and A. Turton, eds.). School of Oriental and African Studies, London.

STRAP. 1995. National Workshop on Strengthening Re-afforestation Programmes in Lao PDR. FAO Regional Project STRAP Field Document No. 4 GCP/RAS/142/JPN.

Tapisuwe, A., J. Whyte and S. Siwatibau. 1998. Participation in conservation in Vanuatu—a field worker's handbook. Island Consulting, Foundation of the Peoples of the South Pacific Regional Office, Port Vila, Vanuatu.

Tapsoba, S.F.I. and K.L.M. Ky. 1999. Etude diagnostique pour une gestion participative de 20 peuplements semenciers au Burkina Faso. CNSF, Burkina Faso.

Tewari, D.D. 1996. Economics of joint forest management programme: a case study of Saliya village, Gujarat, India. Commonwealth For. Rev. 75(3):203–211.

Theilade, I., L. Graudal and E.D. Kjær (eds.). 2000. Conservation of the genetic resources of *Pinus merkusii* in Thailand. Danida Forest Seed Centre Technical Note No. 58, Royal Forest Department (RFD), Thailand/Forest Genetic Resources and Management Project (FORGENMAP), Thailand/FAO of the United Nations, Rome, Italy/Danida Forest Seed Centre, Humlebæk, Denmark.

Theilade, I., P.M. Sekeli, S. Hald and L. Graudal (eds.). 2001. Conservation plan for genetic resources of Zambezi teak (*Baikiaea plurijuga*) in Zambia. Case Study No. 2. Danida Forest Seed Centre, Humlebaek, Denmark.

Thomsen, A. 2000. Integrated tree seed supply strategy for Lao PDR. Draft report from technical consultancy. Lao Tree Seed Project/Danida Forest Seed Centre, Humlebæk, Denmark/Indochina Tree Seed Project.

Thomson, L. 2000. South Pacific Regional Initiative on forest genetic resources (SPRIG)—phase 2. Forest Genetic Resources 28:39–40.

Tsai, L.M. and C.T. Yuan. 1995. A practical approach to conservation of genetic diversity in Malaysia: Genetic resource areas. Pp. 207–218 *in* Measuring and monitoring biodiversity in tropical and temperate forests (T.J.B. Boyle and B. Boontawee, eds.). Proceedings of a IUFRO Symposium held at Chiang Mai, Thailand, 27 August–2 September 1994. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Tumbahanphe, N. 1998. Institutional potentiality and challenges emerging within forest user groups. Project report B/NUKCFP/56, Nepal–UK Community Forestry Project, Kathmandu, Nepal.

Turok, J. 1997. Forest genetic resources and conservation in Central Asia. Forest Genetic Resources 25:71–73.

Turok, J. and Th. Geburek (eds.). 2000. International collaboration on forest genetic resources: the role of Europe. Proceedings of the 2nd EUFORGEN Steering Committee meeting, 26–29 November, Vienna, Austria. IPGRI, Rome, Italy.

Tuxill, J. and G.P. Nabhan. 1998. Plants and protected areas. a guide to *in situ* management. Stanley Thornes (Publishers), Cheltenham, UK.

Tyler, S.R. 1999. Policy implications of natural resource conflict management. Pp. 263-280 *in* Cultivating peace. Conflict and collaboration in natural resource management (D. Buckles, ed.). International Development Research Centre, Ottawa, Canada.

Uraiwan, T-K-Y. 2000. Institutions, livelihoods, and the environment: change and response in mainland Southeast Asia. Conference paper, REPSI/NIAS Conference, Copenhagen, Denmark, 27–29 September.

Vane-Wright, R. 1996. Identifying priorities for the conservation of biodiversity: systematic biological criteria within a socio-political framework. Pp. 309–344 *in* Biodiversity: a biology of numbers and difference (K.J. Gaston, ed.). Blackwell, Oxford, UK.

Wilde, V.L. and A. Vainio-Mattila. 1995a. How to design and implement participatory training programmes. Section 1. Gender analysis and forestry. Forest, Trees and People Programme. FAO of the United Nations, Rome, Italy.

Wilde, V.L. and A. Vainio-Mattila. 1995b. How to design and carry out participatory training workshops. Section 2. Gender analysis and forestry. Forest, Trees and People Programme. FAO of the United Nations, Rome, Italy.

Wilde, V.L. and A. Vainio-Mattila. 1995c. How to use rapid rural appraisal (RRA) to develop case studies. Section 3. Gender analysis and forestry. Forest, Trees and People Programme. FAO of the United Nations, Rome, Italy.

Wily, L. 1997. Villagers as forest managers and governments 'learning to let go'. The case of Duru-Haitemba and Mgori forests in Tanzania. Forest Participation Series No. 9, Forestry and Land Use Programme, International Institute for Environment and Development (IIED), London, UK.

Wily, L., A. Akida, O. Haule, H. Haulle, S. Hozza, C. Kavishe, S. Luono, P. Mamkwe, E. Massawe, S. Mawe, D. Ringo, M. Makiya, M. Minja and A. Rwiza. 2000. Community management of forests in Tanzania—A status report at the beginning of the 21st century. Forest, Trees and People 42:36–45.

Withers, L. A. 1993. New technologies for the conservation of plant genetic resources. Pp. 429–435 *in* International crop science I. Crop Science of America, Madison, WI, USA.

Withers, L. A. and Engelmann, F. 1998. *In vitro* conservation of plant genetic resources. Pp. 57–88 *in* Agricultural biotechnology (A. Altman, ed.). Marcel Dekker Inc. New York, NY, USA.

World Bank. 1996. Decentralization and biodiversity conservation (E. Lutz and J. Caldecott, eds.). Washington, DC, USA.

Worm, K. and B. Morris. 1997. People and plants of Kayan Mentarang. WWF-IP, London, UK.

WWF. 2000. Community based management of Kayan Mentarang National Park. Project document, WWF Denmark and WWF Indonesia.

Yanchuk, A.D. 2001. A quantitative framework for breeding and conservation of forest tree genetic resources in British Columbia. Can. J. For. Res. 31:566–576.

Yanchuk, A.D. and D.T. Lester. 1996. Setting priorities for conservation of the conifer genetic resources of British Columbia. For. Chron. 72:406–415.

Yang, C.-R., F.C. Yeh and A.D. Yanchuk. 1996. A comparison of isozyme and quantitative genetic variation in *Pinus contorta* ssp. *latifolia* by FST. Genetics 142:1045–1052.

Young, A.G. and T.J. Boyle, 2000. Forest fragmentation. Pp. 123–134 *in* Forest conservation genetics (A. Young, D. Boshier and T. Boyle, eds.). CSIRO and CABI Publishing, Wallingford, UK.

ACRONYMS AND ABBREVIATIONS

ACT	Australian Capital Territory
AFLP	amplified fragment length polymorphism
APAFRI	Asia Pacific Association of Forest Research Institutions
APFORGEN	Asia Pacific Forest Genetic Resources Programme
ATO	African Timber Organisation
AusAID	Australian Agency for International Development
BEC	biogeoclimatic
BCFS	British Columbia Forest Service
CAMCORE	Central America and Mexico Coniferous Resources Cooperative
CATCN-PGR	Central Asian and Transcaucasian Network on Plant Genetic Resources
CATIE	Tropical Agricultural Center for Research and Higher Education
CBD	Convention on Biological Diversity
CCB	Centre for Conservation Biology
CGIAR	Consultative Group on International Agricultural Research
CITES	Convention on the International Trade in Endangered Species
CNSF	Centre National de Semences Forestières, Burkina Faso
COGENT	Coconut Genetic Resources Network
COP	Conference of Parties
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DANCED	Danish Cooperation for Environment and Development
Danida	Danish International Develoment Assistance
DBH	diameter at breast height
DFSC	Danida Forest Seed Centre
EUFORGEN	European Forest Genetic Resources
F&L	Forest & Landscape Denmark
FAO	Food and Agriculture Organization of the United Nations
FGR	forest genetic resources
FORGENMAP	Forest Genetic Resources Conservation and Management Programme
FORSPA	Forestry Research Support Programme for Asia and the Pacific
FRIM	Forest Research Institute Malaysia
FSIV	Forest Science Institute of Vietnam
GCF	gene conservation forest
GIS	geographic information systems
GMO	genetically modified organism
GRA	gene resource areas
IBPGR	International Board of Plant Genetic Resources
ICCO	International Cocoa Organization
ICRAF	World Agroforestry Centre (former International Center for Research in Agroforestry)
IFF	Intergovernmental Forum on Forests
INBAR	International Network for Bamboo and Rattan
IPC	International Poplar Commission
IPF	Intergovernmental Panel on Forests

IPGRI	International Plant Genetic Resources Institute
ITGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
ITSP	Indochina Tree Seed Programme
IUCN	World Conservation Union
IUFRO	International Union of Forest Research Organizations
JFM	Joint Forest Management
KVL	Royal Veterinary and Agricultural University
LEUCNET	Leucaena Network
MAS	marker-assisted selection
MUS	Malayan Uniform System
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PRA	participatory rural appraisal
PFE	permanent forest estate
RAPD	random amplified polymorphic DNA
RECOFT	Regional Community Forestry Training Centre
REFORGEN	Global Information System on Forest Genetic Resources
RFD	Royal Forest Department, Thailand
RFLP	restriction fragment length polymorphism
SADC	Southern African Development Community
SAFORGEN	Sub-Saharan African Programme on Forest Genetic Resources
SMS	selective management system
SNP	single nucleotide polymorphisms
SPC	Secretariat of the Pacific Community
SPREP	South Pacific Regional Environmental Program
SPRIG	South Pacific Regional Initiative on Forest Genetic Resources
SSR	simple sequence repeats (microsatellites)
STRAP	Strengthening Re-afforestation Programmes in Asia
STS	sequence tagged site
TEAKNET	Teak Network
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNFF	United Nations Forum on Forests
USDA	United States Department of Agriculture
WWF	World Wide Fund for Nature

INDEX

F

G

GLOSSARY of technical terms

AGROFORESTRY A natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels.

ALLELE An alternative form of a gene. Alleles are located on corresponding loci of homologous chromosomes. They have different effects on the same trait or development processes and can mutate, one to the other. They may affect the phenotype quantitatively and/or qualitatively.

ALLOZYME Isozymes (proteins) whose synthesis is usually controlled by co-dominant alleles inherited by monogenic Mendelian ratios and which show up as banding patterns in electrophoresis.

AMPLIFIED FRAGMENT LENGTH POLYMORPHISM A type of DNA marker, generated by the polymerase chain reaction amplification of DNA treated with enzymes that cut DNA after recognizing a specific sequence. A small portion of restriction fragments is amplified in any one reaction, so that AFLP profiles can be analysed by gel electrophoresis.

BIOLOGICAL DIVERSITY The variety of life forms, the ecological roles they perform and the genetic diversity they contain (sometimes abbreviated to biodiversity).

BIOSAFETY Referring to the avoidance of risk to human health and safety, and to the conservation of the environment, as a result of the use for research and commerce of infectious or genetically modified organisms.

BIOTECHNOLOGY 1. “Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use” (Convention on Biological Diversity). 2. “Interpreted in a narrow sense, a range of different molecular technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals” (FAO’s statement on biotechnology).

BREEDING SYSTEM The system by which a species reproduces. There are several natural systems in plants: (i) outbreeding (exogamy, cross breeding) is a mating system in which mating is between individuals less closely related than average pairs chosen from the population at random. (ii) Inbreeding (endogamy, self breeding) is the crossing of individuals that are more closely related genetically, than individuals mating at random, especially when repeated for several successive generations. (iii) Clonal reproduction. A species may use one or more of these systems.

BUFFER ZONES The region near the border of a protected area; a transition zone between areas managed for different objectives. Isolation area/strip around seed production areas to minimize contamination by pollen from undesirable trees.

CLINAL Related to the variation in one or more phenotypic characters or allele frequencies across an environmental gradient.

CLONAL ARCHIVE A clonal archive (or clone bank) is a collection of genetic individuals which are retained for: (i) the commercial production of propagules, (ii) implementing a breeding strategy, (iii) genetic conservation. The individuals within the clone bank may be raised from seeds but more commonly are grafts whereby the stem, or scion, from the genotype selected in a genetic test have been grafted onto a juvenile rootstock in the nursery prior to planting out in the clone bank. It is common for there to be multiple copies (ramets) of each clone and these are usually planted adjacent to each other within the clone bank.

CONSERVATION (OF A RESOURCE) The actions and policies that assure its continued availability and existence.

CONSERVATION (OF GENETIC RESOURCES) The management of human use of genetic resources so that they may yield the greatest sustainable benefit to present generations, while maintaining their potential to meet the needs and aspirations of future generations.

CRYOPRESERVATION The preservation or storage in very cold temperatures; usually in liquid nitrogen. It is a form of conservation for some seeds and tissues.

DNA MARKER A distinctive, readily identifiable segment of DNA.

DYSGENIC Detrimental to the genetic qualities of future generations. The term applies especially to human-induced deterioration such as may occur through removal of the best phenotypes.

ECOSYSTEM A dynamic complex of plants, animal and micro-organisms communities and their non-living environment interacting as a functional unit.

ECOTYPIC Related to the adaptation of a population or a strain of an organism to a particular habitat.

EFFECTIVE POPULATION SIZE The number of individuals in an ideal population which has the same level of genetic drift and inbreeding as the population from which it is drawn.

***EX SITU* (CONSERVATION)** the conservation of components of biological diversity outside their natural habitats.

FINGERPRINTING Method of identification that compares fragments DNA It is sometimes called DNA typing.

FIREBREAKS A natural or artificial barrier usually created by removing vegetation to prevent or retard the spread of fire.

FOREST MANAGEMENT OR WORKING PLAN: A plan for regulating all forestry activities for a set period of time through the application of prescriptions that specify targets, action and control arrangements.

FRAGMENTATION The process of transforming large continuous forest patches into one or more smaller patches creating areas of geographical discontinuity.

GENE In the genome of an organism, a sequence of nucleotides (DNA sequence) to which a specific function can be assigned.

GENEBANKS A facility where germplasm is stored in the form of seeds, pollen or *in vitro* culture, or in the case of a field genebanks, as plants growing in the field.

GENE FLOW Exchange of genes between populations owing to the dispersal of gametes or zygotes.

GENE POOL The total sum of genetic material of an interbreeding population.

GENE(TIC) CONSERVATION All actions aimed at ensuring the continued existence, evolution and availability of genetic resources.

GENETIC DIVERSITY The sum total of genetic differences between species and within species.

GENETIC DRIFT Change in allele frequency from one generation to another within a population, due to the sampling of finite numbers of genes that is inevitable in all finite-sized populations. The smaller the population, the greater is the genetic drift, with the result that same alleles are lost, and genetic diversity is reduced.

GENETIC EROSION Gradual loss of genetic diversity.

GENETIC RESOURCES The economic, scientific or societal value of the heritable materials contained within and among species.

GENETIC VARIATION Variation due to the contribution of segregating genes and gene interactions.

GENETICALLY MODIFIED ORGANISM The broad term used to identify organisms that have been manipulated by molecular genetic techniques to exhibit new traits. Also known as genetically engineered organisms.

GENOTYPE The sum total of the genetic information contained in an organism or the genetic constitution of an organism with respect to one or a few gene loci under consideration.

GERMPLASM The total genetic variability available to a particular population of organisms, represented by the pool of germ cells (sex cells, the sperm or egg) or plant seeds. Also used to describe the plants, seeds, or other parts useful in plant breeding, research, and conservation efforts, when they are maintained for the purpose of studying, managing, or using the genetic information they posses (same as genetic resources).

HETEROZYGOSITY The proportion of heterozygous individuals at a locus or of heterozygous loci in an individual. He - expected heterozygosity; Ho - observed heterozygosity.

HETEROZYGOUS An individual is heterozygous for a particular locus when two different alleles are present at that locus.

INBREEDING Mating between individuals that have one or more ancestors in common, the extreme condition being self-fertilization, which occurs naturally in many plants.

INFLORESCENCE A cluster of flowers generated on the same stalk.

IN SITU (CONSERVATION) The conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

INDIGENOUS SPECIES Species existing in, and having originated naturally in, a particular region or environment.

INTRASPECIFIC GENETIC VARIATION Genetic variation within a species.

ISOZYME Multiple forms of a single enzyme.

KEYSTONE SPECIES A species having major influences on ecosystem structure and function, which are not replaceable by another member of the community.

LOCUS (PL. LOCI) A stretch of DNA at a particular place on a particular chromosome.

METAPOPULATION A group of populations of the same species coexisting in time but not space.

MOLECULAR MARKER A molecular selection technique of DNA signposts which allows the identification of differences in the nucleotide sequences of the DNA in different individuals.

OUTCROSSING RATE Proportion of seed derived by crossing between unrelated individuals.

PARENT TREES A pollen donor and/or ovules producer.

PHENOTYPE The observable characteristics of an individual, resulting from the interaction between the genotype and the environment in which development occurs.

PHYLOGENETIC Referring to phylogenesis, or the evolutionary history of a particular taxonomic group, usually a species.

PIONEER SPECIES The first species or community to colonize or re-colonize a barren or disturbed area, thereby initiating a new ecological succession (used synonymously with colonising species).

POLLINATOR A living organism transferring pollen, e.g. insect, bird or bat.

POPULATION A group of individuals of the same species occupying a defined area and genetically isolated to some degree from other similar groups.

POPULATION DYNAMICS Changes taking place during a population's life.

PROVENANCE The geographical and/or genetic origin of an individual.

RANDOM AMPLIFIED POLYMORPHIC DNA A polymerase chain reaction-based genotyping technique, in which an RNA or a single-stranded DNA molecule is amplified with single, short, randomly chosen primers.

RECALCITRANT SEED Seed which is desiccation-sensitive, with a short hydrated life-span in storage typically ranging from a few days to several months. Recalcitrant seed behaviour is most prevalent in tree species from tropical, humid zones with larger seeds (>3-5 g).

RESTRICTION FRAGMENT LENGTH POLYMORPHISM A class of genetic marker base on the detection of variation in the length of restriction fragments generated when DNA is treated with enzymes that cut DNA after recognizing a specific sequence. Differences in fragment lengths arise due to genetic variation with respect to the presence or absence of specific recognition site(s).

SELF(ING) To pollinate with pollen from the same flower or plant.

SINGLE NUCLEOTIDE POLYMORPHISMS A genetic marker resulting from variation in sequence at a particular position within a DNA sequence. This type of marker is commonly the result of single base substitutions and deletions. Such variation is extensive throughout all genomes, and offers the particular advantage of being detectable without the need for gel electrophoresis.

SIMPLE SEQUENCE REPEATS (MICROSATELLITES) A segment of DNA characterized by a variable number of copies (typically 5-50) of a sequence of around 5 or fewer bases (called repeat units). At any one locus (genomic site), there are usually several different "alleles" in a population, each allele identifiable according to the number of repeat units. This existence of multiple alleles (high level of polymorphism) has enabled microsatellites to be developed as powerful markers in many different species. They are detected by the polymerase chain reaction.

SEQUENCE TAGGED SITE Short unique DNA sequence that can be amplified by the polymerase chain reaction and thus tagged to the site on the chromosome from which it was amplified.

SOMACLONAL VARIATION Epigenetic or genetic changes induced during the callus phase of a plant cell cultured *in vitro*. Sometimes visible as changed phenotype in plants generated from culture.

THINNING Gradual removal of trees crowding or shading the preferred species or individuals.

Forest & Landscape

IPGRI

This guide is the first volume in a series of three booklets that deals with the conservation of forest (tree and shrub) genetic resources. This volume gives an overview of concepts and systematic approaches to conservation and management of forest genetic resources. It outlines the need to conserve these resources and focuses on some of the strategies that may be employed in doing this. In addition, the volume focuses on planning national conservation of forest genetic resources, identification of research needs in forest resources, people's participation in the conservation of forest genetic diversity, and regional and international approaches to the conservation of forest genetic resources.